THE UNIVERSITY OF ALBERTA

LIFE HISTORY TYPES OF THE LEAST CISCO (*COREGONUS SARDINELLA*, VALENCIENNES), IN THE YUKON TERRITORY NORTH SLOPE AND EASTERN MACKENZIE RIVER DELTA DRAINAGES

by

© GARRY JAMES MANN

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF ZOOLOGY

EDMONTON, ALBERTA

SPRING, 1974

Frontispiece: Sled Dogs at Paulatuk, N.W.T.: the principal consumers of the native domestic catch of least cisco.

ABSTRACT

The first detailed study of the alternate life-history types and growth patterns of the least cisco (*Coregonus sardinella*, Valenciennes) in the western Canadian Arctic was conducted during the ice-free months of 1972 and 1973. Samples were collected from freshwater lakes and coastal brackish water areas on the north slope of the Yukon Territory as well as from eastern Mackenzie River Delta drainages. Life history types examined included anadromous, freshwater migratory and freshwater lake-resident (non-migratory) populations. Two cases of sympatric occurence of dwarf ($<$150 mm fork length at maturity) and normal ($>$200 mm fork length at maturity) growth types are described for two lakes.

Among normal populations, brackish water least cisco were observed to have the most rapid growth rate, at least for the first 10 years of life. The greatest longevity occurred in freshwater lake resident populations ($>$20 years). Growth in length becomes asymptotic at 10 years of age in normal populations and at 3 to 4 years of age in dwarf populations. Dwarf cisco in Trout Lake, Yukon Territory, could be distinguished from similar-sized normal juveniles only by dissection which revealed advanced gonad development. Considerable

niche overlap occurs between dwarf and juvenile normal cisco in terms of areas occupied and feeding habits. Normal cisco begin maturing at age 5 or 6 but 100% maturity does not occur in most populations examined until age 7 or 8. Dwarf specimens were found to be mature at age 3. A small percentage of mature individuals in all populations do not spawn in consecutive years. These resting-stage cisco were found to occur most commonly in samples of older (12+ years) females.

Spawning egg diameter is approximately 1.5mm. Spawning occurred prior to fall freeze-over in Peter Lake, Northwest Territories (mid to late September) with dwarf fish preceding normal by approximately 10 to 15 days. Trout Lake, Yukon Territory, cisco appeared to spawn in early October after fall freeze-over.

Stomach analysis showed that all populations of least cisco in the study areas are generalists and opportunists in feeding habits. Bottom, pelagic and surface food items were commonly found in stomachs at all times during the study period.

Brackish water least cisco differed significantly ($p<0.05$) from all other populations in terms of gillraker, pyloric caeca and lateral-line scale counts. Trout Lake dwarf fish had significantly fewer gillrakers ($p<0.05$) than Trout Lake normals and all other populations of least cisco which were examined ($p<0.01$).

ACKNOWLEDGEMENTS

This study was generously financed by Northern Engineering Services Company Limited and Canadian Arctic Gas Company Limited. I sincerely thank these companies for their continued support and for allowing considerable time and facilities to be made available to conduct this research as a portion of their overall environmental impact assessment program.

I am particularily indebted to Dr. P.J. McCart and Dr. J.S. Nelson for their expert guidance during the planning and field data collection phases of this project.

Sincere thanks are extended to all members of the field crews who kindly sacrificed their time to assist in data collection during 1972 and 1973, including Mr. Hugh Bain, Mr. Mark deBruyn, Mr. Gordon Glova and Mr. Dirk de Graaf.

I am grateful for the helpful suggestions for improvement of the manuscript provided by Dr. J.S. Nelson, Dr. P.J. McCart, and Dr. David Cass.

My sincere thanks are also extended to the secretarial staff of Aquatic Environments Limited for their patient assistance in the

drafting of figures, and the typing and editing of the various drafts.

Finally, I would like to thank my wife for her continual moral support and for putting up with my long absences which were necessary during the field seasons.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHIC PLATES

INTRODUCTION

The circumpolar least cisco (*Coregonus sardinella*, Valenciennes) is commonly found in the brackish-water areas of the Arctic seas and in freshwater streams and lakes in Asia and North America. A wide variety of life history types are exhibited across its range, varying from true anadromy to freshwater, landlocked populations, and from large-bodied migratory types to dwarf non-migratory forms (McPhail and Lindsey, 1970).

This species is utilized extensively in the northern USSR for commercial purposes (Venglinskii, 1967) and to a much lesser degree as a native domestic food source in the Alaskan and Canadian Arctic (Wynne-Edwards 1952, Stein *et al*, 1973). Results of the present study and of studies conducted in the past (Hatfield *et al*, 1972, Stein *et al*, 1973, Cohen, 1954) suggest that the least cisco of the North American Arctic probably cannot sustain any high-yield commercial harvesting.

With such a widespread distribution and abundance in the western North American Arctic, it is surprising that so little is known about the ecology and life history of the least cisco. A good deal more attention has been paid to its taxonomic status than to its biology by both Asian and North American authors.

The present studies were initiated as part of an overall environmental impact assessment program in the Northern Yukon and Northwest Territories, prior to possible construction of a large-diameter gas pipeline from discovery areas along the Alaskan and Canadian Arctic coasts to southern Canadian and US markets. This study represents the first detailed study of the ecology of the least cisco in the Canadian Arctic and, it is hoped, will contribute to the background knowledge that will be necessary for future management of this species.

LITERATURE REVIEW

The most extensive study carried out on *C. sardinella* in North America to date, was done by Cohen (1954) and Wohlschlag (1954), on several populations near Point Barrow, Alaska. These authors have documented the existence of two morphologically, physiologically and behaviourally distinct groups within the species in their area. One form is anadromous (or at least migratory) and attains a maximum length of about 360 mm but is slower growing than the other, non-migratory form which attains a maximum length of only 220 mm. Basically, two well-marked forms of the least cisco exist: a large form often caught in or near the sea, and a small form usually found in lakes. (McPhail and Lindsey, 1970).

Cohen and Wohlschlag both distinguished the two forms which they studied on the basis of body coloration and meristic characters: a migratory form which is heavily spotted on the back and dorsal fin and has a higher mean gillraker count and; the non-migratory form which is never spotted and has a lower mean gillraker count. The migratory habits of least cisco have been reported for populations in Siberia (Berg, 1948-49), Alaska (Cohen 1954, Wohlschlag, 1953,-54,-56, Alt and Kogl, 1973) and Canada (Mackenzie River) (Hatfield *et al*, 1972, Wynne-Edwards, 1952). All these authors report a late summer-early autumn migration into rivers by mature fish, presumably for spawning,

followed by non-spawning and immature fish. Walters (1955) suggests that this is an arctic adaptation to escape temperatures below $0^{o}C$ which may occur in sea water during the winter months. A review of other methods of freezing avoidance, including freezing point depression of blood serum by concentration of glycoproteins, in arctic and antarctic fishes is provided by DeVries (1971).

The feeding habits of the least cisco have not been extensively studied although Berg (1948-49) reports that anadromous cisco in the brackish waters of estuaries and lagoons feed primarily on amphipods. Both Berg (1948-49) and Hatfield *et al* (1972) report a cessation of feeding by mature individuals on spawning migrations. Venglinski (1967) reports that 'Ryapushka' (*C. sardinella*) in the Ob River drainage of Siberia feed mainly on gammarids and copepods in the winter, but in the summer change to mainly zooplankters (including: *Cyclops* sp., *Diaptomus* sp., *Limnocalanus* sp., and Bosminidae).

Cohen (1954) and Wohlschlag (1954) have published the most complete data on age and growth of the least cisco to date. Observations on growth of cisco from the Mackenzie River, NWT and the Colville River, Alaska have recently been published by Hatfield *et al* (1972) and Alt and Kogl (1973) respectively. Cohen and Wohlschlag both reported that eggs spawned in September about the time of fall freeze-up, hatched out under the ice and the fry developed scales during the following summer. Nothing is known of spawning behaviour and spawning site selection, or of the egg incubation time for this species in North America. The early freeze-up and late spawning season of least cisco have undoubtedly contributed to this gap in the knowledge of this

species. Cohen and Wohlschlag postulated that a number of age-specific survival effects of an unknown nature were acting such that the migratory forms lived longer on the average than the non-migratory forms. The migratory fish captured in freshwater lakes were found to be uniformly heavier than those captured in the estuaries. Such factors as salinity, temperature, light and food could affect embryological development and later growth in the cisco. Of all the habitats examined in the Alaskan study (lakes, streams, marine and brackish waters), the streams would have the most variability of all factors except salinity and the authors postulated that this might account for the growth peculiarities of *C. sardinella* from Point Barrow.

Behnke (1972) has reviewed the systematics of ciscoes and other salmonids. He describes the current confusion in coregonid taxonomy and places *C. sardinella* in the sub-genus *Leucichthys*, along with other ciscoes, so as to distinguish them from the other coregonid groups: *Coregonus (sensu stricto) (ie: Coregonus clupeaformis* complex), *Prosopium* sp. and *Stenodus*. This concurs with Nikolsky and Reshetnikov (1970). The current center of controversy directly concerned with the taxonomy of the 'Ryapushka' or least cisco group, deals with the recognition of *C. albula* and *C. sardinella* as distinct species in Asia. Most Soviet ichthyologists agree that these are two subspecies since in most cases the two forms cannot be consistently separated on morphological grounds, and the majority of populations are allopatric (Behnke, 1972). However, both 'species' have been found to have examples of sympatric, reproductively isolated popula-

tions as well as geographic races. (McPhail and Lindsey, 1970).

In North America the *C. sardinella* group is well separated from the *C. artedii* complex on the basis of morphological and biochemical evidence (McPhail and Lindsey, 1970). The range of divergence within the *C. sardinella* of North America has been little studied. The extent of the known variation is summarized in McPhail and Lindsey (1970). Recent evidence indicates the existence of a third form of the least cisco in North America, distinguishable from the coastal migratory and freshwater non-migratory forms by its extremely small body size at maturity. Dwarf populations of this nature have been reported from Naknek Lake and Iliamna Lake of the Bristol Bay area of Alaska (McPhail and Lindsey 1970). The present study presents data for two more such populations of dwarf least cisco in the areas studied. At the risk of confusing the taxonomy of coregonids even further, it is suggested that the dwarf forms may be sufficiently differentiated to be considered sibling species.

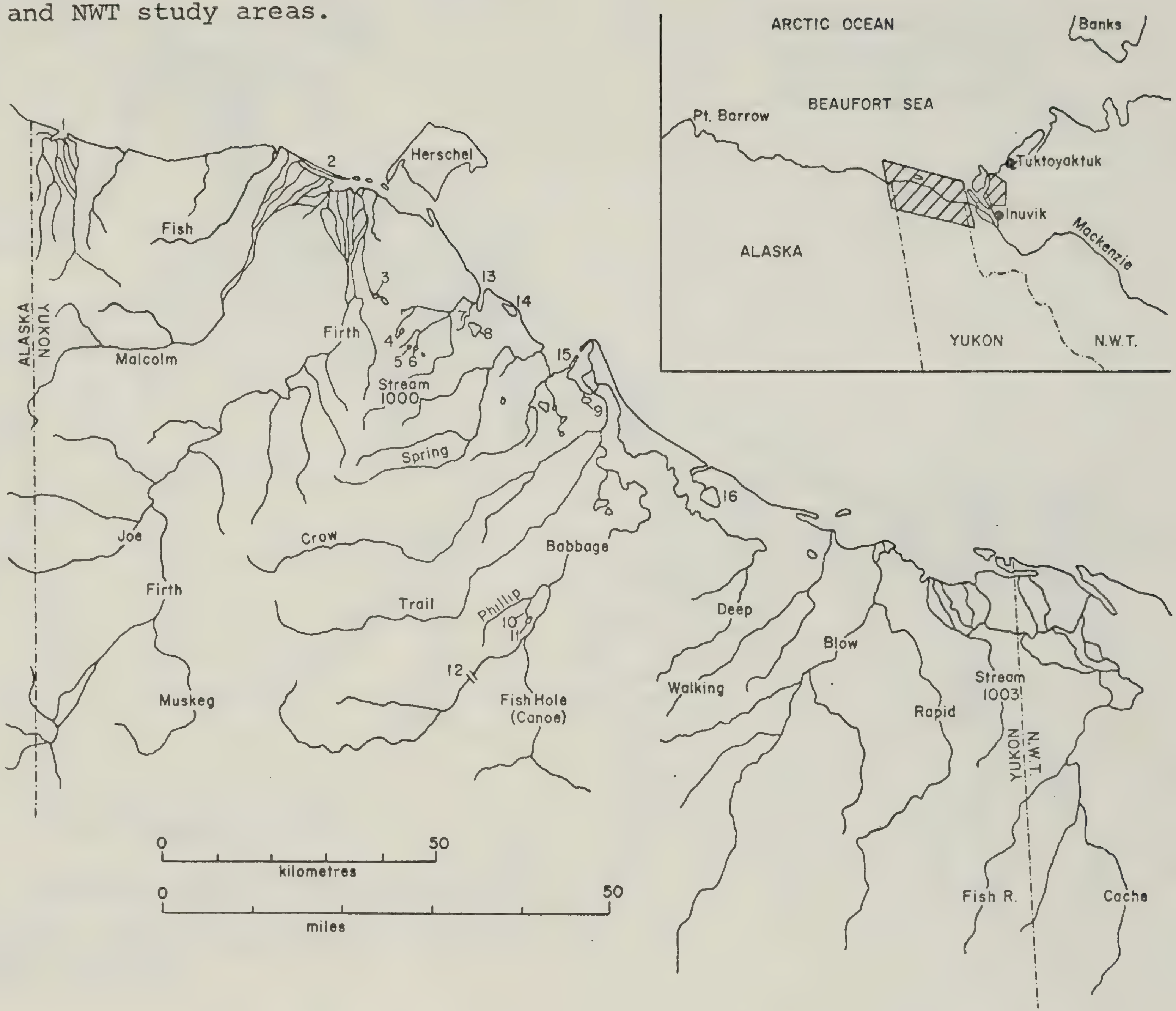
THE STUDY AREAS

The sampling program for least cisco was carried out from late May to early September in 1972 and from late June until late September in 1973. Due to the short summer season of the study area, it was possible to sample during three of the four seasons in the 3-1/2 to 4-month field program each year, by being present from spring break-up to fall freeze-over.

This study was conducted as part of a more general helicopter-supported study of the fish fauna of the Yukon North Slope and eastern Mackenzie River drainages. It was therefore possible to cover an extremely large area with relatively little difficulty. In the 1972 field season, studies were restricted to the Yukon North Slope (Figure 1). This is an area of roughly 8,000 square miles, bounded by the Alaska-Yukon border on the west, the Mackenzie Delta on the east, the Beaufort Sea Coast on the north, and by the headwaters of the drainages of the North Slope in the British Mountains to the south. In 1973, surveys were conducted along the drainages of the east bank of the Mackenzie River along the proposed development corridor. Studies in this area were of a less intensive nature and were restricted primarily to occasional visits to stations on streams for purposes of fish, benthos and chemical sampling.

Figure 1. Yukon North Slope study area. Insert of Yukon and NWT study areas.

1 Clarence Lagoon
2 Nunaluk Spit
3 Firth Lake
4 Lake 107
5 Lake 108
6 Lake 105
7 Stream 1001
8 Lake 100
9 Lake 106
10 Trout Lake Outlet
11 Trout Lake
12 Babbage Falls
13 Roland Bay
14 Stokes Point Lagoon
15 Phillips Bay
16 Sabine Lake



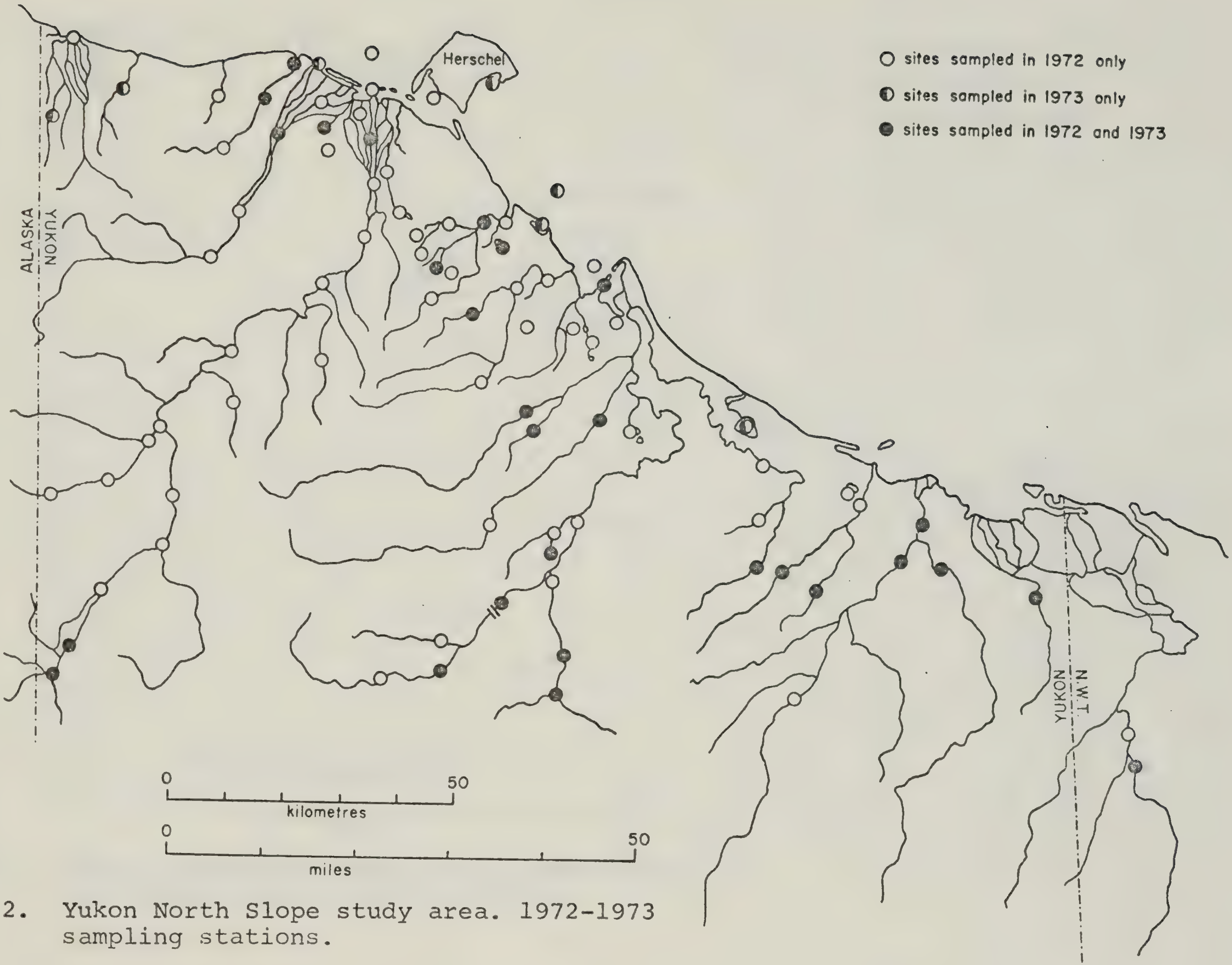


Figure 2. Yukon North Slope study area. 1972-1973 sampling stations.

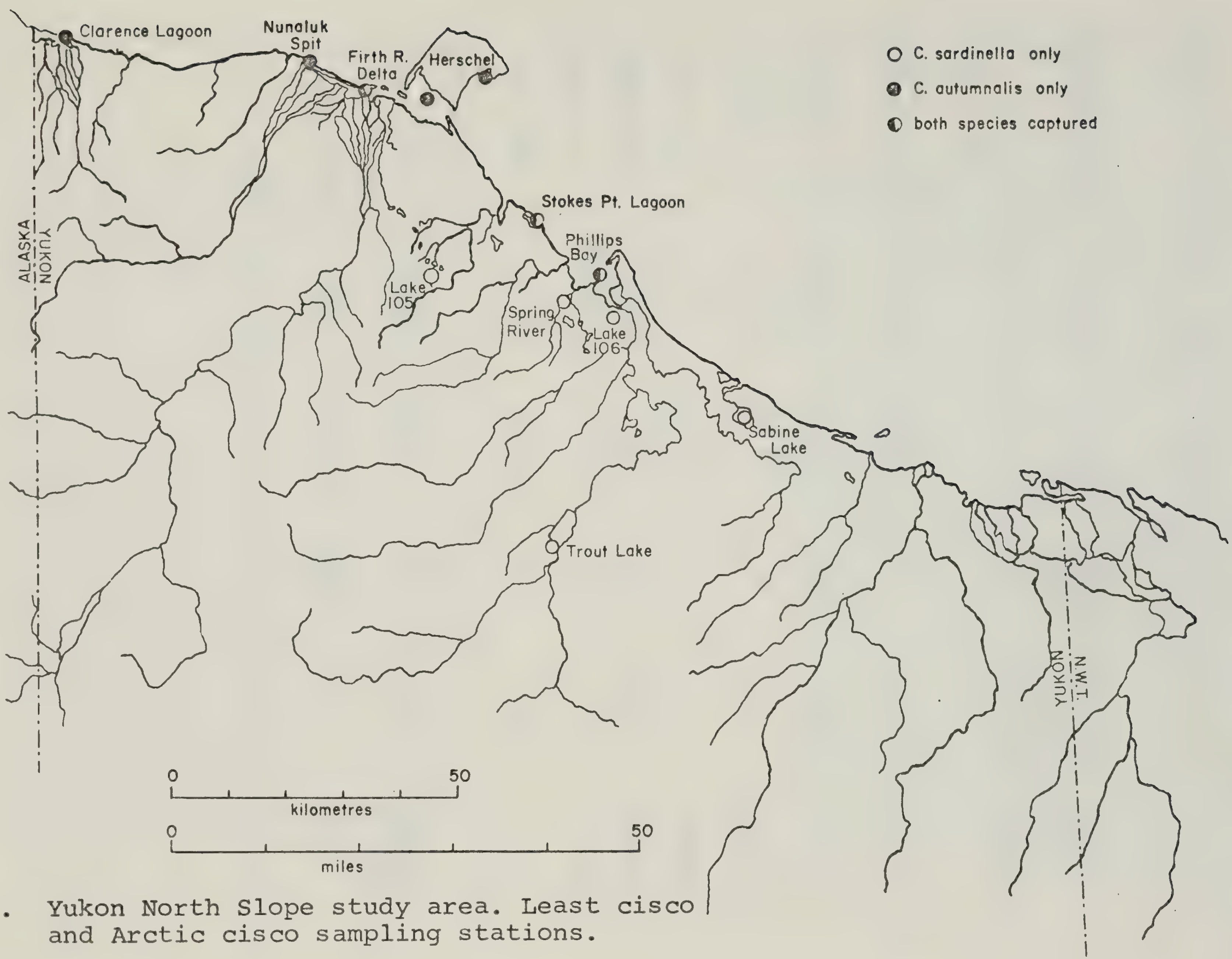


Figure 3. Yukon North Slope study area. Least cisco and Arctic cisco sampling stations.

TABLE 1: Least cisco sampling stations, 1972, 1973.

Locality Name	Lat.	Long.	Elevation (M)	Surface Area (Hectares)	Max. Depth (M)
North Slope:					
Firth R. delta, Nunaluk Spit	69°33'	139°30'	0	---	3
Stokes Point Lagoon	69°20'	138°46'	0	266.7	3.5
Phillips Bay	69°15'	138°31'	0	---	2 (estimated)
Lake 106	69°14'	138°31'	0	---	unknown
Sabine Lake	69° 3'	137°50'	~59.5	284.6	unknown
Lake 105	68°18'	139°10'	152.4	11.2	12.5
Trout Lake	68°50'	138°44'	152.4	68.5	9.0
East Mackenzie:					
Peter Lake	68°45'	134° 9'	91.4	451.9	unknown (>15M)
Holmes Creek	69° 2'	134°15'	<30.5	---	<1

Although not all drainages and water bodies could be tested during the study, a large number of streams, rivers and lakes on the Yukon North Slope were sampled and it is believed that the studies provide a reasonably good estimate of the fishery resources of this area. Figure 1 shows place names and sampling sites on the Yukon North Slope. Figure 2 indicates all locations on the North Slope which were sampled as part of the general surveys. *Coregonus sardinella* was commonly caught in the same nets with the Arctic cisco (*C.autumnalis*) in coastal waters. Figure 3 indicates stations at which each species occurred.

Table 1 lists the locations, altitude, surface area (where applicable) and maximum depth for stations at which least cisco were captured.

The lower Firth River-Nunaluk Spit station was sampled repeatedly during the 1972 field season. The physical and chemical characteristics of this study site were typical of the entire Beaufort Sea coastal study area. The site was sampled as soon as open water appeared in late May. Sampling was ineffective due to the shallow nature of the estuary and the difficulty experienced in keeping gillnets free of debris that was constantly being washed out by the Firth and Malcolm rivers. Sea ice in coastal areas was not fully broken up and dispersed until approximately July 10, 1972. This area also exhibited a typical barrier-beach formation common to the Beaufort coast of Alaska and the Yukon (Plate 1). These beaches of coarse sand and gravel are built up as a result of the ocean surf

Plate 1. A barrier beach near Phillips Bay (Mainland to the right background).

Plate 2. Connection between a coastal lagoon and Beaufort Sea. (Beaufort Sea in background).

piling up the outwash from the major rivers and streams. Wave action has resulted in the formation of shallow, protected estuaries on the landward side. The waters of these areas range from fresh to slightly saline and appear to be highly productive. Crustacean fauna (Amphipoda, Copepoda and Isopoda) is particularly abundant and the estuaries are heavily utilized by fish in the summer months as feeding areas. Unfortunately this study did not allow sufficient time to quantify benthos and plankton in these areas. However, evidence of the abundance of crustaceans was provided on two occasions when 50 to 60% of an overnight gillnet catch was consumed by amphipods and isopods before retrieval.

The Phillips Bay sampling station was similar to the lower Firth Delta-Nunaluk Spit station, in that the water was constantly turbid, shallow and had a slight salinity stratification. (Appendix 5). This area and the nearby body of water labelled Lake 106 appear to be extensions of the Babbage River Delta. A greater diversity of fish species was observed at this station than at any other station examined during the study (Appendix 1). Lake 106 appears to be merely an inland extension of Phillips Bay since the water remained constantly turbid and since the species diversity in the two bodies of water was similar.

Two coastal lagoons were sampled during this study: Clarence Lagoon near the Alaskan border, and Stokes Point Lagoon, located between the Firth and Babbage River deltas.

Although Clarence Lagoon could only be sampled on three

occasions during 1972, it appeared as if this water body was not as heavily utilized as a feeding area as other coastal sampling sites. Least cisco were not taken here. The lagoon is almost uniformly shallow (<1m) except for a deeper channel (2.5 m) along the west bank through which the Clarence River flows. The salinity in this water body did not approach the brackish range (>15 parts per thousand) on any sampling occasion. The lagoon was connected to the Beaufort Sea by a narrow channel (~10 m in width) in which there was a continuous seaward flow.

Stokes Point Lagoon, although similar in area, differed significantly from Clarence Lagoon. This body of water was uniformly deeper (to 3.5 m) and was not under the influence of a major stream. Consequently it exhibited a much more pronounced salinity stratification. Sampling was conducted here with gillnets at approximately 2-to 3-week intervals in 1973. Temperature-salinity profiles were taken on each occasion and the results are summarized in Figure 4. A salinity-temperature stratification occurred during spring, early summer and fall. Water temperatures were low when ice was present in the nearby Beaufort Sea, but rose sharply during the month of August when easterly winds blew the ice floes far off shore. Salinity stratification within the lagoon was most pronounced in the spring and fall. For most of the month of August the entire water column was uniformly saline (>15 ppt). This was presumably due to a summer decrease in surface run-off and a decreased freshening effect.

Tidal fluctuations in the Arctic ocean are very small and therefore have little effect on coastal lagoons in the study area.

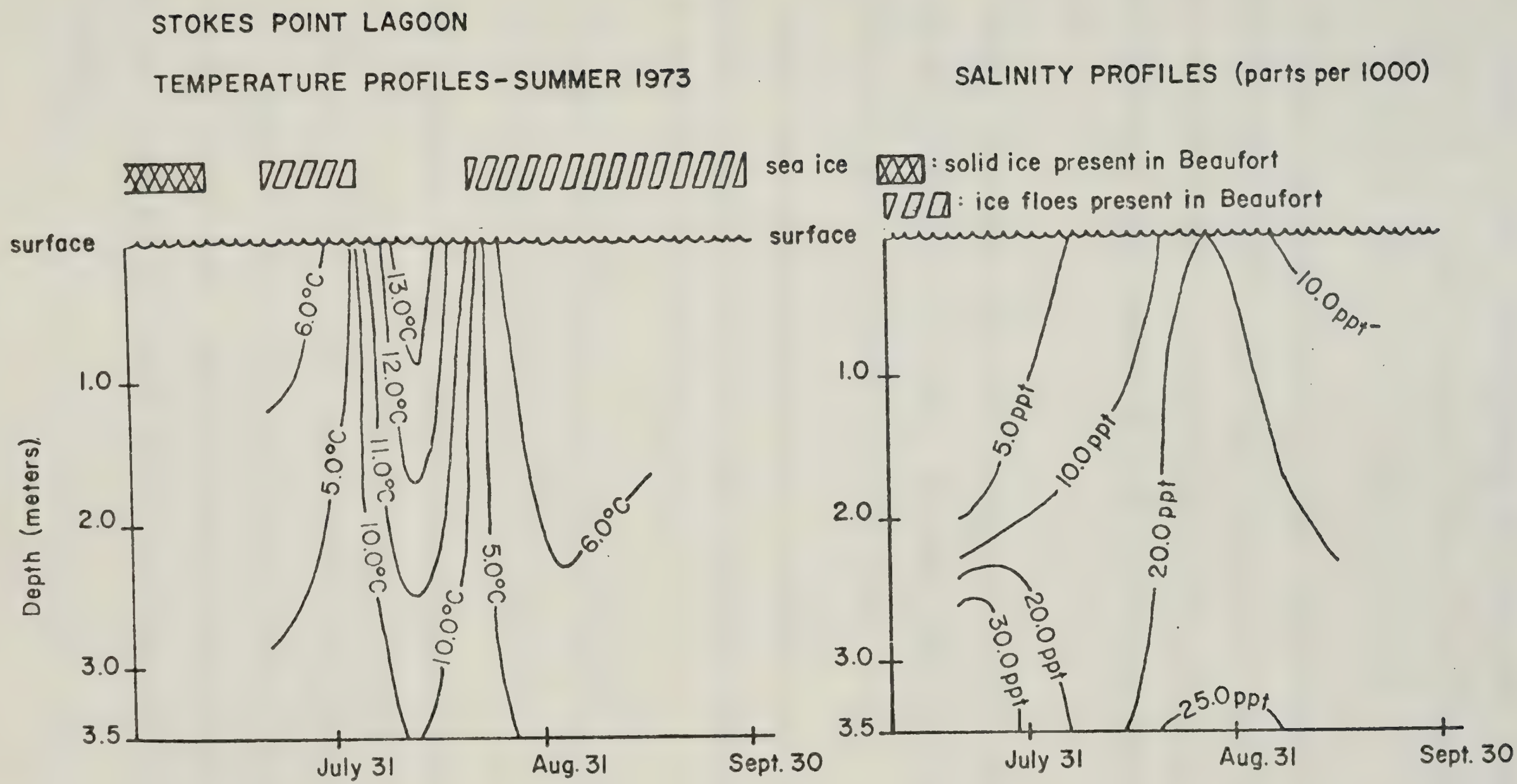


Figure 4. Salinity and temperature profiles, Stokes Point Lagoon, 1973.

The only evidence of tide observed during this study was a current which was observed on several occasions flowing into Stokes Point Lagoon in the morning and out in the evening (Plate 2).

The erosion-deposition effects of wave action appear to significantly affect coastal morphology. During the 4-month study period in 1973, the connection between Stokes Point Lagoon and the Beaufort Sea shifted approximately 15 to 20 meters in a westward direction.

Several freshwater lakes were sampled on the Yukon North Slope and in the East Mackenzie survey area. Of these, only 3 in Yukon and 3 in the Mackenzie area were found to contain least cisco.

Sabine Lake on the North Slope was test-netted late in 1973. Unfortunately, it was too late in the study to obtain a large enough sample of least cisco for life history study.

Two other lakes, Trout Lake and Lake 105 on the Yukon study area, were sampled intensively during both 1972 and 1973.

The 3 lakes in the East Mackenzie survey area which were found to contain least cisco populations were Peter Lake (see Figures 8, 9, Table 1), Yeltea Lake (Lat. $67^{o}00'$ Long. $129^{o}30'$) and Lake 73 - 1-2 (Lat. $68^{o}15'$ Long. $134^{o}01'$). Only Peter Lake was netted intensively during the 1973 field season. However, despite regular gillnet sampling, least cisco did not appear in the catch from this lake until early September.

Of the two lakes in the Yukon study area which were studied intensively, samples were most easily obtained from Trout Lake. The name is misleading since no trout or trout-like fish are present in the lake (see Appendix 1). The lake is located on the Babbage River drainage and is surrounded by rolling foothills (Figure 5, Plate 3). Water levels appear to be maintained by surface runoff from the surrounding terrain; no distinct inlet streams could be located. The lake outlet is located on the northwest corner and connects to the Babbage River via Phillip Creek. The actual point of exit from the lake is rather indistinct, with the water flowing through an area of thick sedge before coming together to form a narrow channel, 1/2m in width. This stream freezes solid in winter but was observed to be flowing by mid June. There is no evidence that least cisco migrate in and out of the lake. Electrofishing and other sampling was carried out along the outlet, Phillip Creek and the Babbage River at various times during the 1972 field season. At no time were least cisco encountered in catches. Arctic grayling were taken in the Trout Lake outlet and these fish may utilize this stream for spawning (deBruyn and McCart, 1973).

Trout Lake, located at an altitude of approximately 152.4 m (500 ft), has a surface area of 68.5 har and a maximum depth of 9 m (see Figure 5). It receives considerable wind action after spring breakup, which occurred on approximately June 25 and June 29 ($\pm$ 3 days) in 1972 and 1973, respectively. The lake was nearly isoclinal on July 8, 1972 (surface: 14°C, 4 m: 12.7°C, bottom (7 m):8.8°C) and

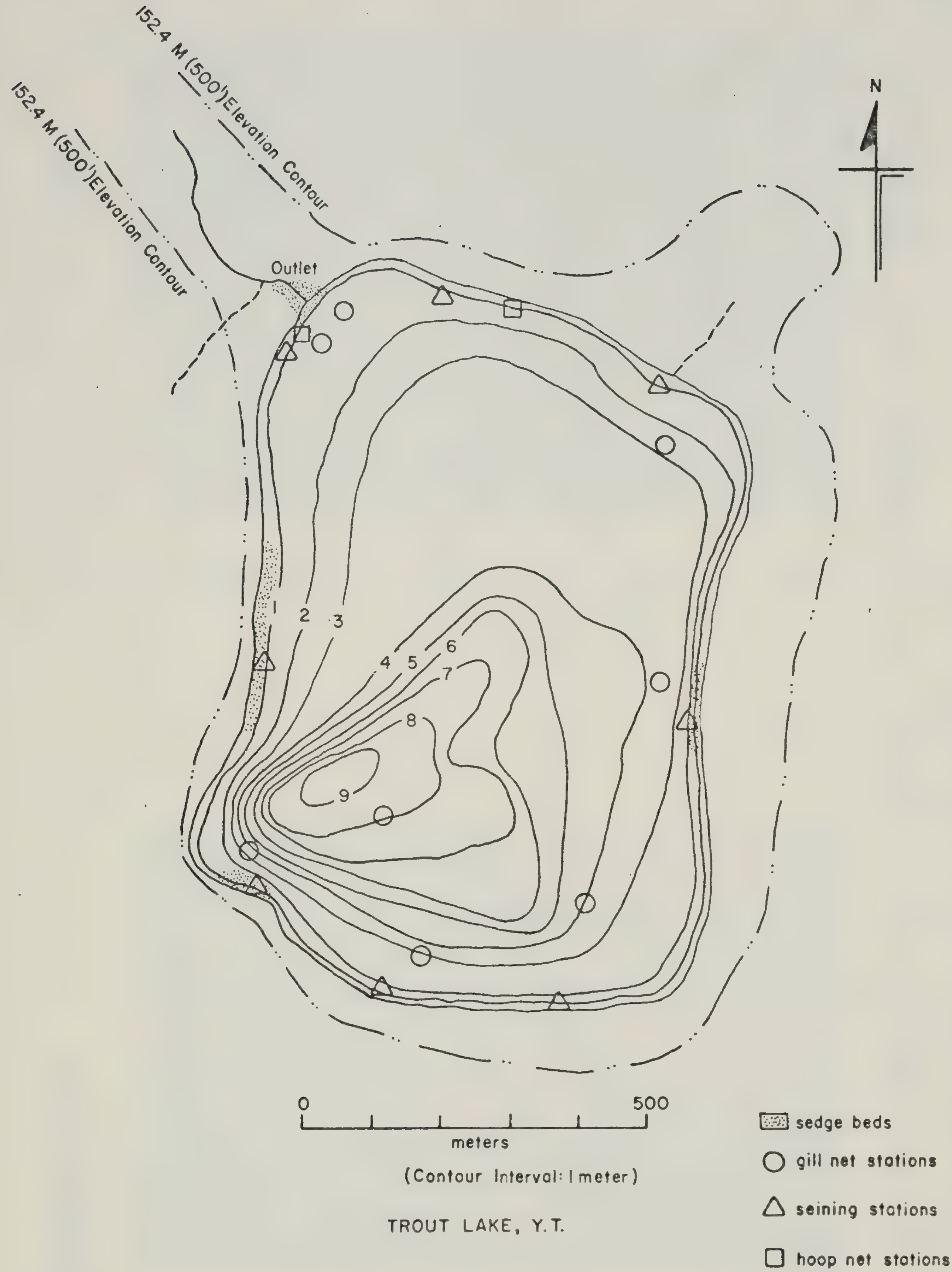


Figure 5. Trout Lake, YT contour map.

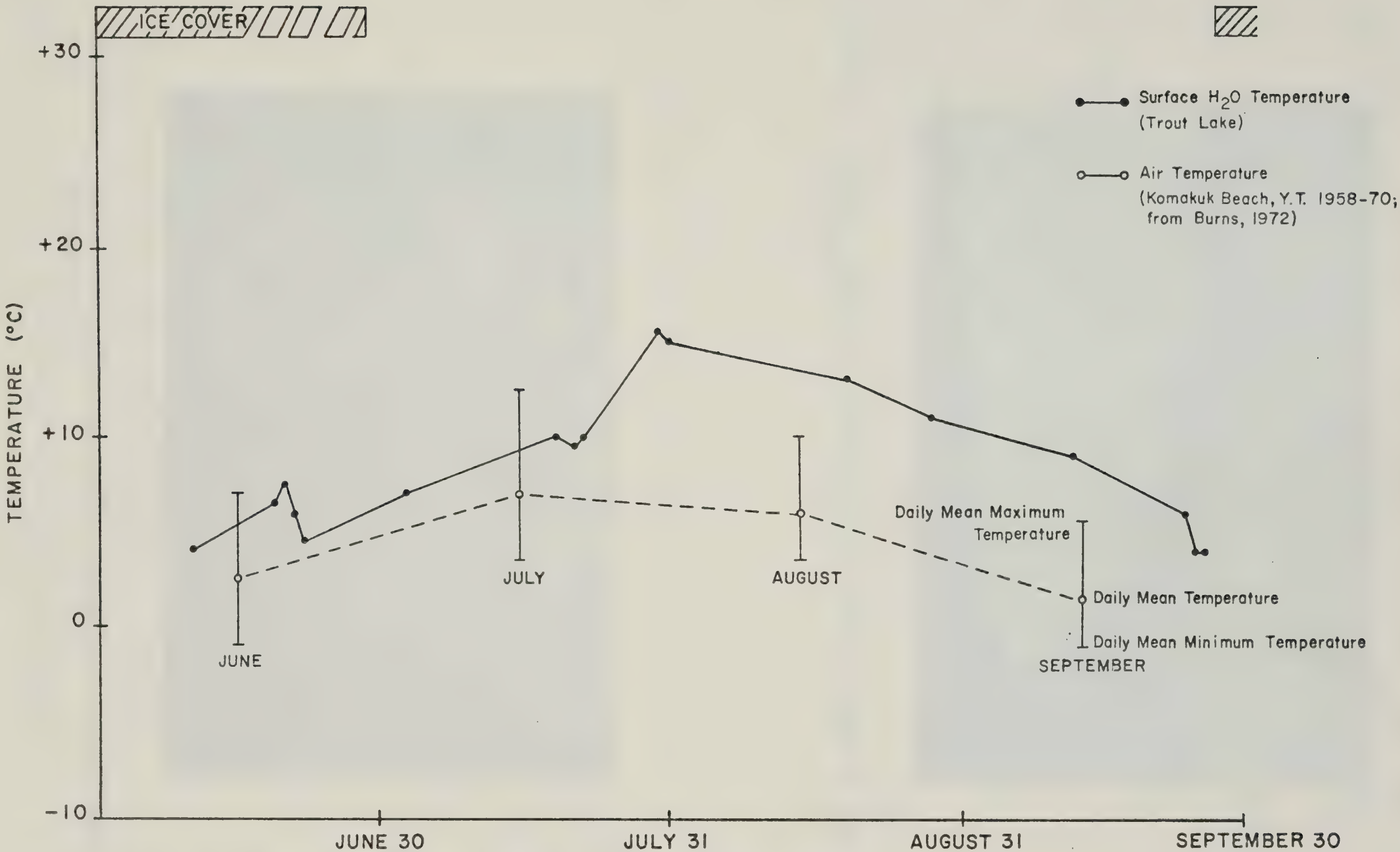


Figure 6. Trout Lake surface water temperatures, 1973, and Komakuk Beach air temperatures (1958-70, from Burns, 1972).

Plate 3. Trout Lake, YT June 1973. (North towards top of photo).

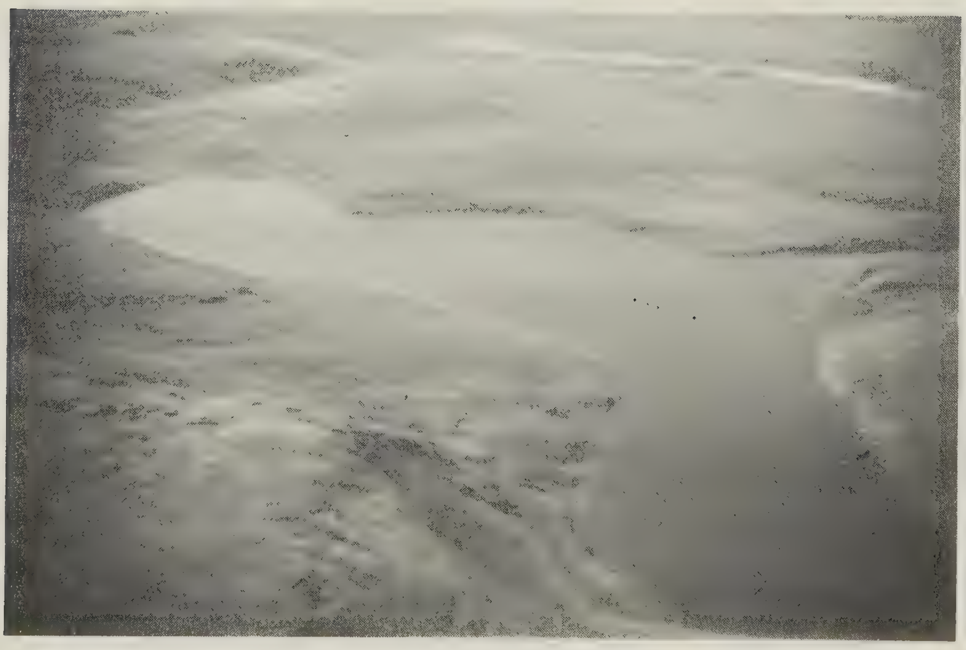


Plate 4. Lake 105, YT July 1972. (North to the right of photo).

saturated with oxygen throughout the water column (surface: 13 ppm, bottom: 14.0 ppm). Surface water temperatures during the 1973 sampling program are summarized in Figure 6. Daily mean air temperatures (1958-70) for Komakuk Beach weather station, located approximately 100 km to the northwest, are also presented (from: Burns, 1972). The majority of the nearshore bottom consists of clay-ooze but large areas of shale-fragment beach are present on the north and south perimeter of the lake. Rooted aquatic vegetation is sparse (Figure 5) and consists primarily of sedge. The surrounding terrestrial vegetation consists of small clumps of dwarf birch (*Betula* sp.) and dwarf willow (*Salix* sp.), but the majority of the lake shore is barren of any deciduous growth.

The second population of non-migratory *C. sardinella* that was intensively studied on the Yukon North Slope was located in Lake 105 (unnamed on topographic maps). This lake is also located at approximately 152.4 m (500 ft), 50 km northwest of Trout Lake (Figures 1, 3, 7, Plate 4) and is one of a chain of long, narrow, deep water bodies that occur in a discontinuous trench at the 152.4 m (500 ft) contour. This trench appears as if it may be a rift or fault or possibly an old glacial river channel (Hughes, 1972). In spite of their similarity, each lake in the chain has a unique fish fauna. Lake 105 was found to contain a relatively large population of least cisco as well as Arctic grayling and lake trout (Appendix 1). The lake has a surface area of 11.2 har, and a maximum depth of 12.5 m. A distinct inlet is located at the west end which had a relatively constant flow of approximately .09 to .11 m^3 per second (m^3/sec) throughout the

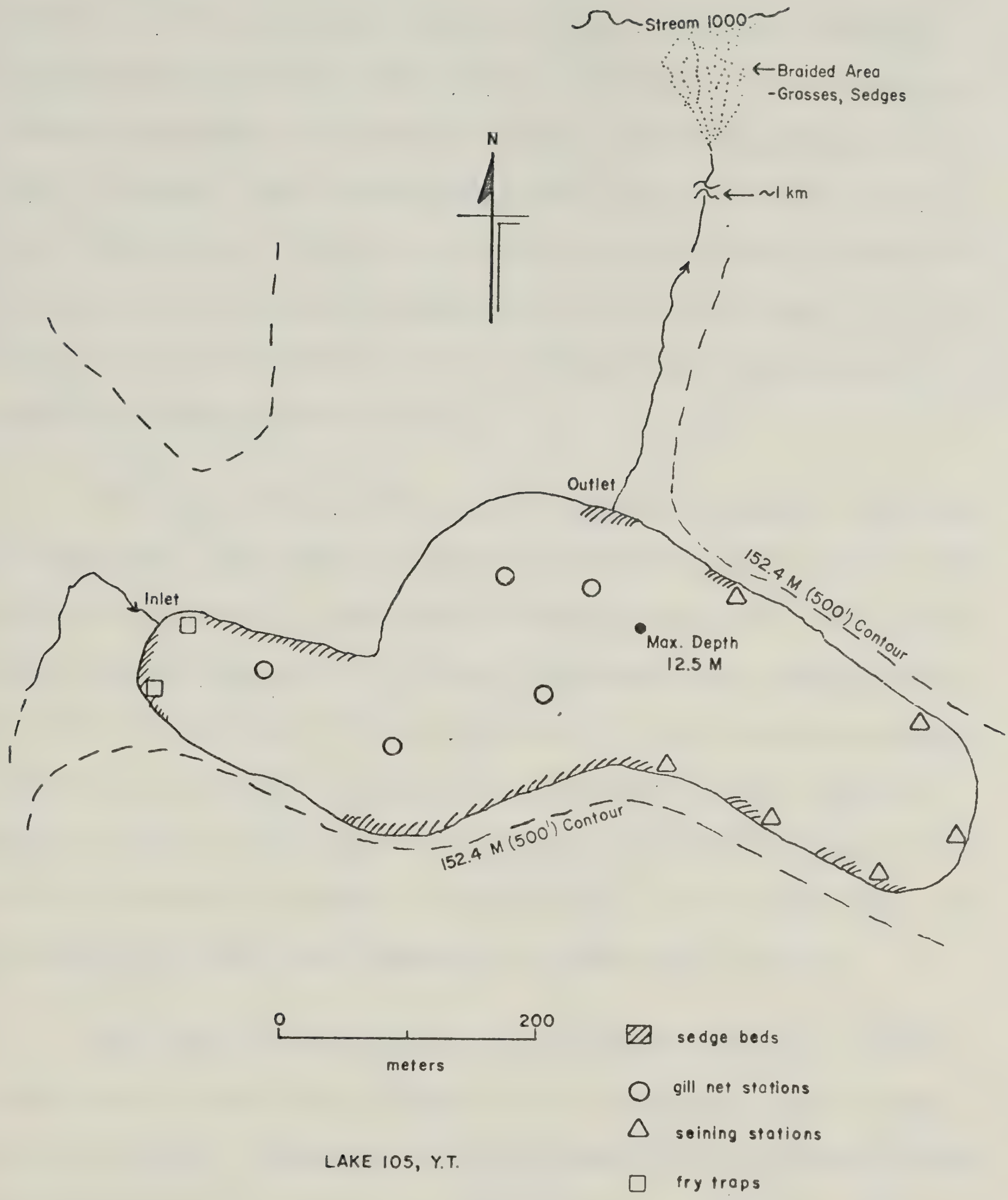


Figure 7. Lake 105, YT, showing sampling sites and aquatic vegetation beds.

study period. The lake appears to be fed by surface runoff and from melting snow banks in the ravines to the south of the lake. The outlet is on the north shore and it too had a reasonably constant discharge throughout the study (0.09 to .11 m^3/sec). This stream was occupied throughout the summer by juvenile and adult grayling. However, it appears highly unlikely that any fish could enter or leave this stream since it braids into many tiny rivulets once it enters the coastal plain, prior to entering nearby Stream 1000 (Figure 7). For this reason, it is believed that this population of least cisco is also land-locked and non-migratory.

The third lake population of *C. sardinella* examined was found in Peter Lake, NWT, which is located approximately 48 km (30 mi) north of the town of Inuvik. This lake is the uppermost lake in the Holmes Creek drainage (Figure 8). A single ripe female cisco obtained from the lake in October of 1972 led us to believe that a resident population might be present. Sampling was carried out in this lake and others in the drainage system at irregular intervals throughout the 1973 field season. However, it was not until early in September, 1973 that any more least cisco appeared in catches from this lake.

The lake itself is located in rolling tundra terrain immediately north of tree line (Figures 8, 9). No distinct inlet streams could be located. However, the outlet stream flowed constantly during the study at 0.43 to 0.57m^3/sec.(estimated) and appeared to form no barrier to fish passage. The lake has a surface area of 451.9 har, and a small island is located at the north end near the outlet. The maximum depth is unknown but it is believed to be deeper than 15 m

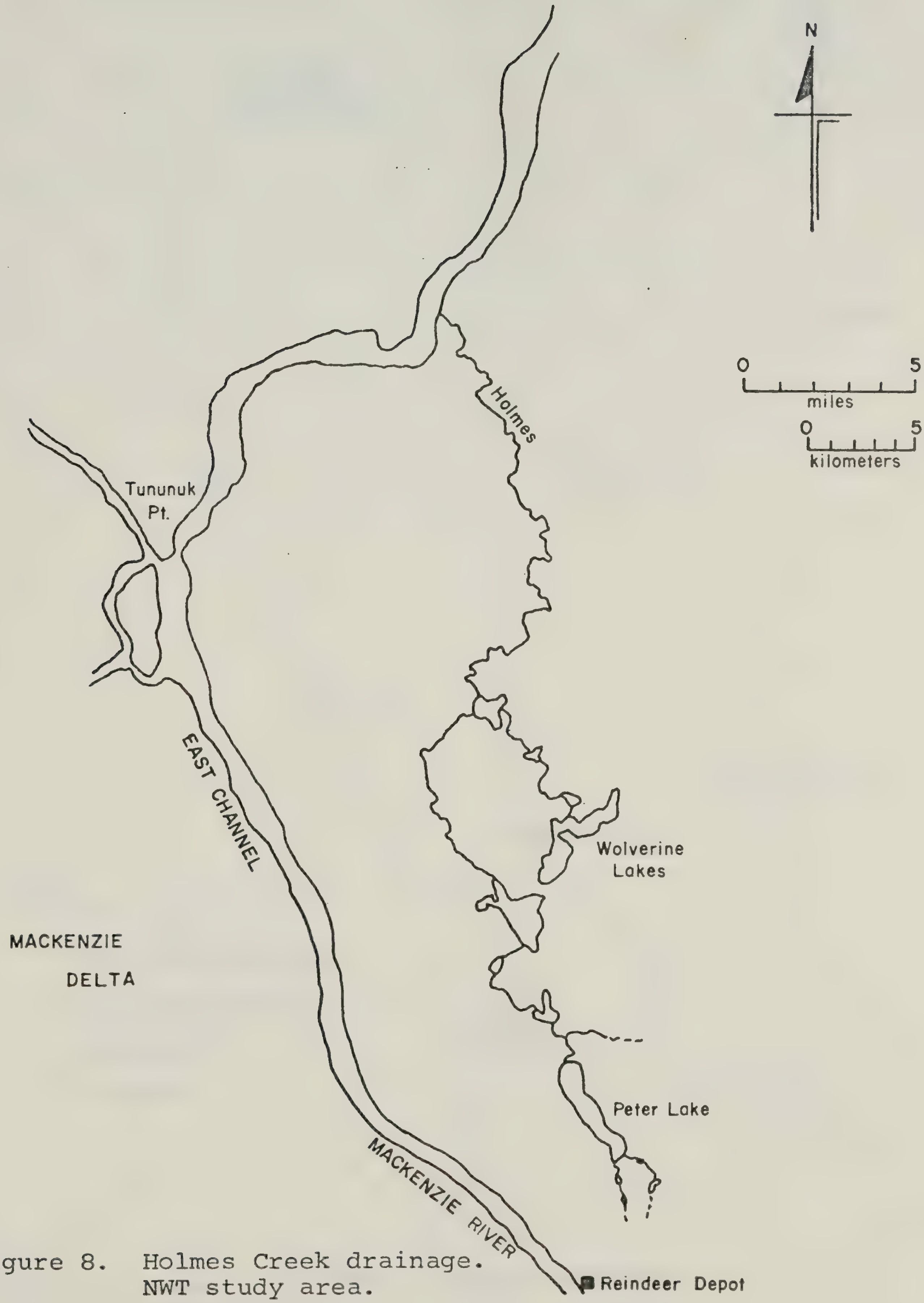


Figure 8. Holmes Creek drainage. NWT study area.

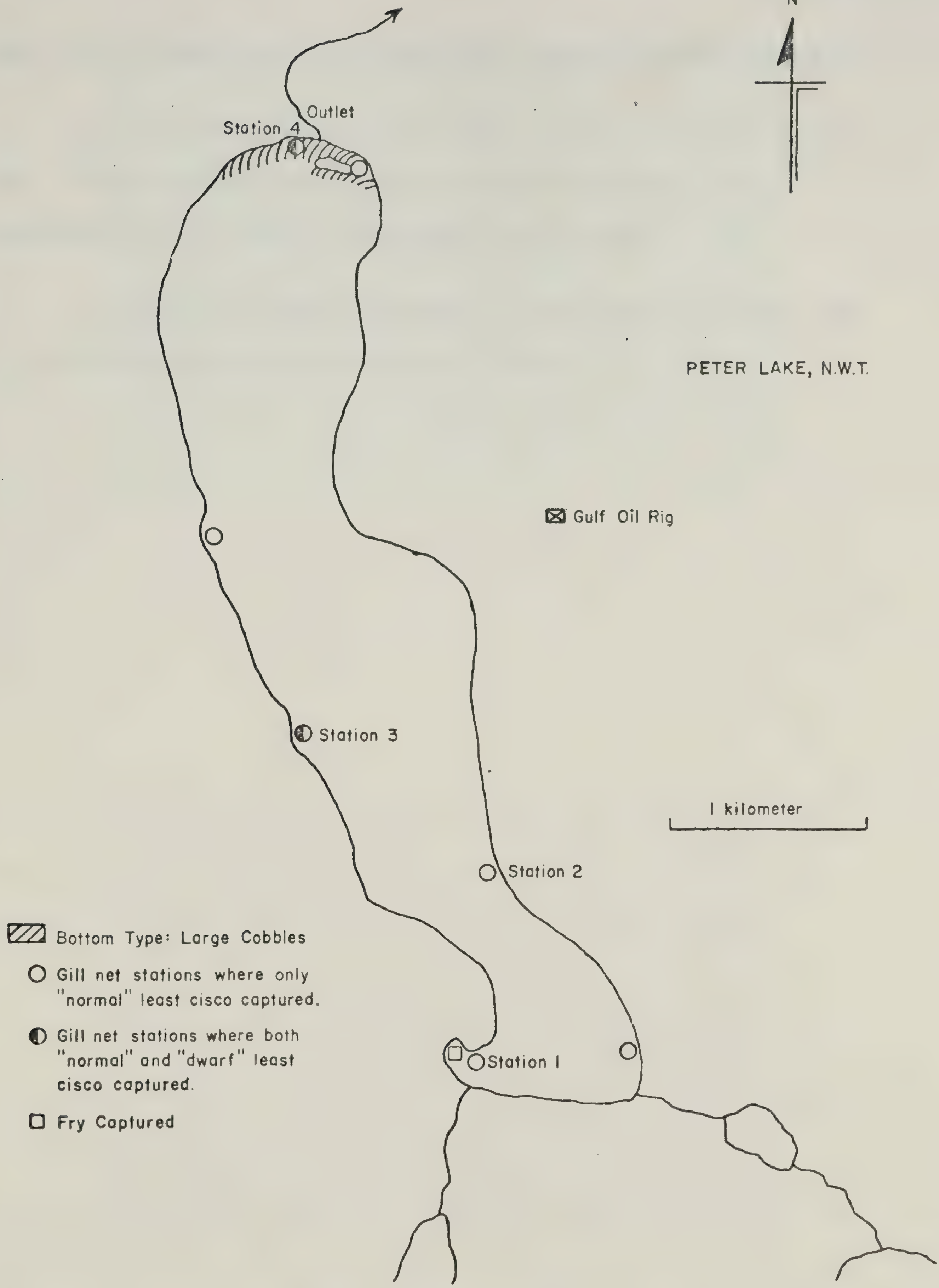


Figure 9. Peter Lake, NWT, sampling stations.

since nets set near shore were set at this depth on several occasions.

An oil rig was located on the eastern side of the lake during 1972, 1973 and considerable angling pressure on the lake trout population of Peter Lake was reported by the rig crew.

A hydrological study is presently being conducted on the lake by the Canadian Federal Water Resources Branch.

MATERIALS AND METHODS

During the 1972 field season, operations were conducted from a base camp located near the Firth River on the Yukon North Slope (Figure 2, Plate 5) and access to sampling sites was by helicopter. Since the area to be surveyed during the 1973 field season was expanded to include the east Mackenzie River drainages, operations were based out of the town of Inuvik. A temporary field camp was set up on Lake 100 on the Yukon North Slope and used on occasions when extensive sampling was to be conducted in the Yukon study area (Plate 6).

A total of 1,544 least cisco were captured and analysed during the 1972-1973 study periods. In 1972, 789 were taken from the Yukon North Slope area. In 1973, a further 755 fish were taken from both Yukon and NWT study areas. A summary of the cisco catch data is presented in Appendix 2.

A wide variety of methods of collection were employed during the fisheries studies. Equipment used included monofilament gillnets of various mesh sizes, beach seines of various lengths, back-pack electro-fishing units, a hoop net, fry traps, fish weirs and angling. Only gillnets, beach seines and the hoop net were successful in capturing least cisco; of the total sample, gillnets captured 81.1% (1,260), seine nets 18.4% (284), and the hoop net 0.5% (8).

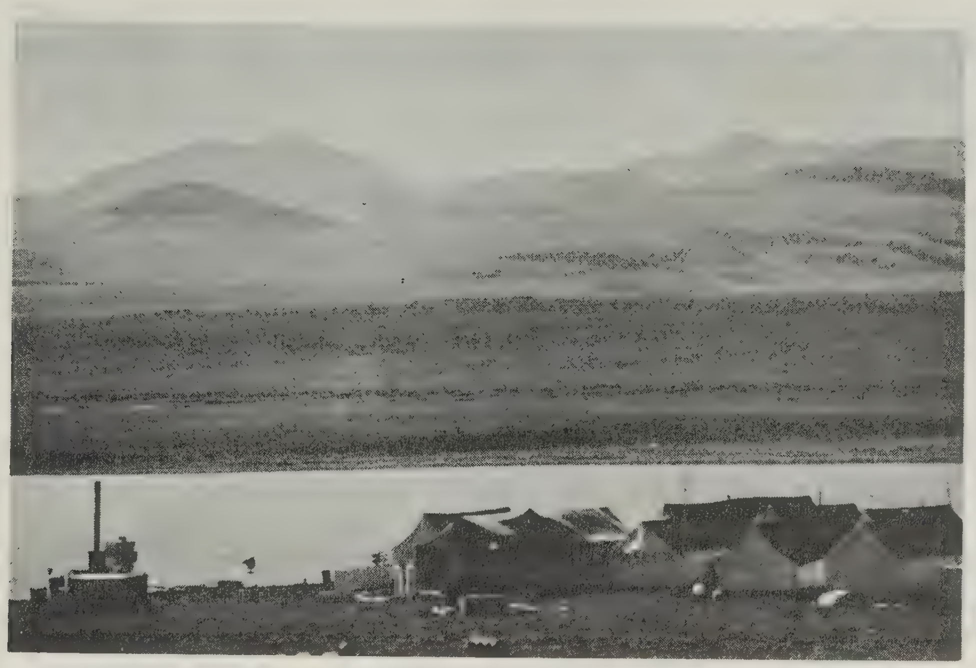


Plate 5. Field base camp near Firth River, YT (June 25, 1972).

Plate 6. Field camp, Lake 100, North Slope YT (July 20, 1973).

Gillnets employed in this study were of the monofilament type, 2.4 m (8 ft) in depth and 15.24 m (50 ft) in length. Mesh sizes employed were 1.0, 1.3, 2.5, 3.8, 5.1, 6.3, 7.3, 8.9, 10.2, 11.5cm (1/2", 3/4", 1", 1-1/2", 2", 2-1/2", 3", 3-1/2", 4", 4-1/2") stretched measure. Nets were set in a variety of depths of water and normally in gangs of up to 6 nets. Early in the studies, mesh sizes were set such that as wide a range of fish sizes as possible could be obtained in a sample. Individual mesh sizes proved to be selective for specific length classes (Appendix 3). Nets could therefore be set selectively to obtain whatever size-classes were needed at any particular time. A hoop-trap net was set (in Trout Lake) on two occasions only. It proved to be selective for larger least cisco ($>$172 mm fork length) and grayling (deBruyn and McCart, 1973).

Fine mesh ($\sim$5 mm) beach seine nets were used extensively in Trout Lake and Lake 105 for the capture of young-of-the-year and juvenile least cisco. In some cases, circumstances dictated the use of unusual methods of capturing specimens (Plate 8).

In most cases, samples of fish captured were analyzed fresh in field or base camps (Plate 7). Samples which could not be looked at immediately were frozen for later analysis. Data were recorded on data sheets (Appendix 4) and coded in the manner shown. Fork length was recorded using a measuring board, and weights were measured to the nearest 0.1 gm using a triple-beam balance. Weights of less than 1.0 gm were measured to the nearest .01 gm using a torsion balance. Egg diameters were determined to the nearest 0.1 mm by finding the

Plate 7. Field dissection laboratory, 1972.

Plate 8. Seining in Beaufort Sea using helicopter.

mean diameter of ten eggs lined up in a row, using calipers. Scales that were to be used for aging were cleaned with the fingers and pressed between two glass slides, taped together and an individual collection number assigned. Otoliths were removed and placed in glycerol in 1-dram vials, labelled individually and stored for later aging. Aging was carried out using a binocular dissecting microscope for both scales and otoliths at 40X magnification. Individual scales and otoliths were each aged independently twice. Where the first and second readings differed, a third reading was used to reconcile them. Length and weight data were obscured during the first aging so as not to bias results, but these data were referred to during the second aging to eliminate gross errors. Criteria for establishing age are discussed under "Age and Growth", page 36.

Stomachs from least cisco captured in 1972 were individually labeled and fixed in 10% formalin for later examination. In the 1973 field season, stomach contents were identified in the field. Since the large majority of fish were captured in gillnets and the length of time from capture to analysis was highly variable, no data were recorded concerning relative stomach fullness or the relative abundance of individual organisms within stomachs. Feeding data were simply analyzed in terms of percent occurrence within the total sample.

Fecundity counts were conducted only for ovaries which were judged to be mature and green in condition. Fecundity was estimated by counting a sub-sample constituting approximately 100% of the total ovarian weight. Total ovarian weights and the weights of sub-samples were determined during field dissection and the latter preserved

TABLE 2: Fecundity estimation: accuracy check.

Sample No.	Location	Subsample Estimation	Actual Count	Difference	Percent Error
N72-137-32	L-105	3,923	4,260	-337	7.9
N72-137-34	L-105	4,350	4,403	- 53	1.2
N72-137-24	L-105	7,277	6,623	+654	9.8
N72-111-4	Trout L.	7,445	7,886	-441	5.6
N72-111-10	Trout L.	8,747	10,353	-1,606	15.8

Mean Error = 8.6%

for later counting. The total fecundity was determined by simple proportion:

$$\frac{\text{Fecundity sub-sample}}{\text{total fecundity}} = \frac{\text{Weight sub-sample}}{\text{weight total ovary}}$$

A check of the accuracy of this technique was made by direct count of total numbers after the sub-sampling method had been employed. The mean error was discovered to be 8.6%, with the smallest error occurring for the ovaries with the lowest total count and the largest error occurring for the highest total count. (Table 2).

The state of maturity and condition of adult fish were estimated in the field during dissection. On the basis of gonad weight and width and egg diameter, fish were judged to be either mature or immature. All mature individuals were assigned a condition factor: green (G) if the male or female appeared to have sufficient gonadal development to spawn in the fall of the year of sampling; ripe (R) if, in the case of males, sperm could be easily stripped from the gonad when stroked in the posterior direction or, in the case of females, if the eggs had been dropped free of the ovarian tissue into the body cavity; will not spawn (WS), if the apparently mature individual did not exhibit sufficient gonadal development to participate in the fall spawning season of the year in which it was captured. (method according to McCart, Craig and Bain, 1972). This method is clearly subjective, particularly with regard to judgement between the larger individuals which may be closely approaching maturity and smaller-bodied adult individuals which have spawned but are in a resting stage. The chance of misjudgement here is reasonably great. In the

case of males, the chance of error is even greater since mature, green individuals do not develop large gonads until quite late in the summer. Females which had previously spawned often showed evidence of this in the form of eggs retained in the ovary.

Taxonomic data were recorded for a series of least cisco from each area sampled during the 1972 field season and supplemented by data for 1973 collections. Meristic counts taken were number of lateral line scales, gillrakers (first arch on left side), pyloric caeca and vertebra. Methods used were after Hubbs and Lagler (1958) and Lindsey (1961). Pyloric caeca and gillraker counts were made from specimens fixed in 10% formalin. Vertebral counts were obtained from x-ray film examined on a light table. Counting commenced with the first vertebra posterior to the occiput and terminated with the most posterior vertebra in the hypural complex.

RESULTS AND DISCUSSION

Age and Growth

Aging Techniques and Criteria

As mentioned in the previous section, aging of specimens was carried out, for the first year's data at least, by using scales and otoliths. The use of scales has been demonstrated to give reasonable accuracy for coregonids at temperate latitudes by a number of authors (see Lux 1971, Lagler 1952). The primary difficulty encountered is that, in very slow-growing populations, annuli may be unrecognizable near the perimeter of the scale because of the "dense edge" (Nordeng 1961) due to the extreme crowding or possible failure to lay down circuli. McCart *et al* (1972), Nordeng (1961) and others have recommended the use of otoliths for aging Arctic char and other slow-growing Arctic salmonid species, since the alternation of hyaline (slow winter growth) and opaque (rapid summer growth) layers can be easily detected right to the perimeter of the otolith in most cases.

Scales and otolith ages tend to agree closely for the younger age classes, as has been found in Arctic char by McCart *et al* (1972) and Nordeng (1961). Once growth becomes asymptotic (*ie* when maximum length is closely approached), the agings become more divergent.

Apparent growth rates determined from scales tend to exceed those determined from otoliths and the maximum age determined from otoliths significantly exceeds that from scales. Figures 10 and 11 demonstrate this relationship for the Trout Lake and Lake 105 populations of least cisco. Plate II shows the clarity of annuli on some otoliths.

The time of hatching of least cisco eggs that were spawned the previous fall is not known for the populations studied. However, near Point Barrow, Alaska, hatching is believed to occur under the ice, prior to spring breakup (Cohen 1954). The first hyaline ring on otoliths observed close to the focus may be caused by the yolk sac resorption after hatching and by the metabolic changes which occur as the larval fish begins foraging for its own food. In the least cisco otoliths, this larval check is growth was often not visible. However, the check caused by cessation of growth during the following winter was normally clearly visible. (Plate 12). Time of year in which the fish was captured was kept in mind while reading otoliths and scales. Fish captured in the early spring or summer whose otoliths did not show any opaque deposition around the perimeter were aged by counting the number of annuli and adding one for the edge of the otolith. Thus, in this study, the age of a fish from hatching is regarded as the number of annuli which could be counted, taking into consideration the date of capture of the individual. Since greater confidence could be expressed in the ages determined from otoliths, than in those determined from scales, the otolith ages have been used exclusively in all computations in this report.

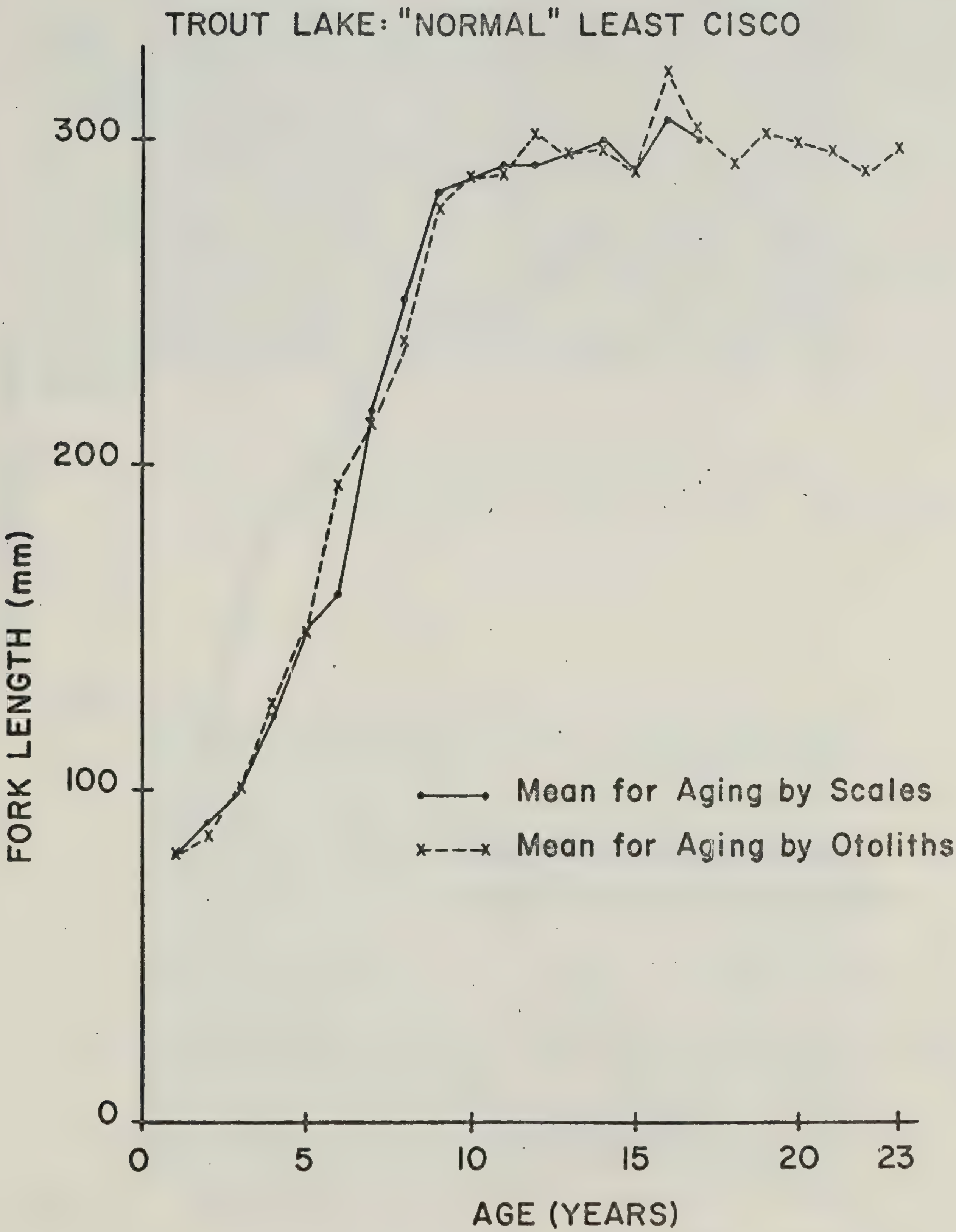


Figure 10. Age-length relationship, Trout Lake: scale vs otolith ages.

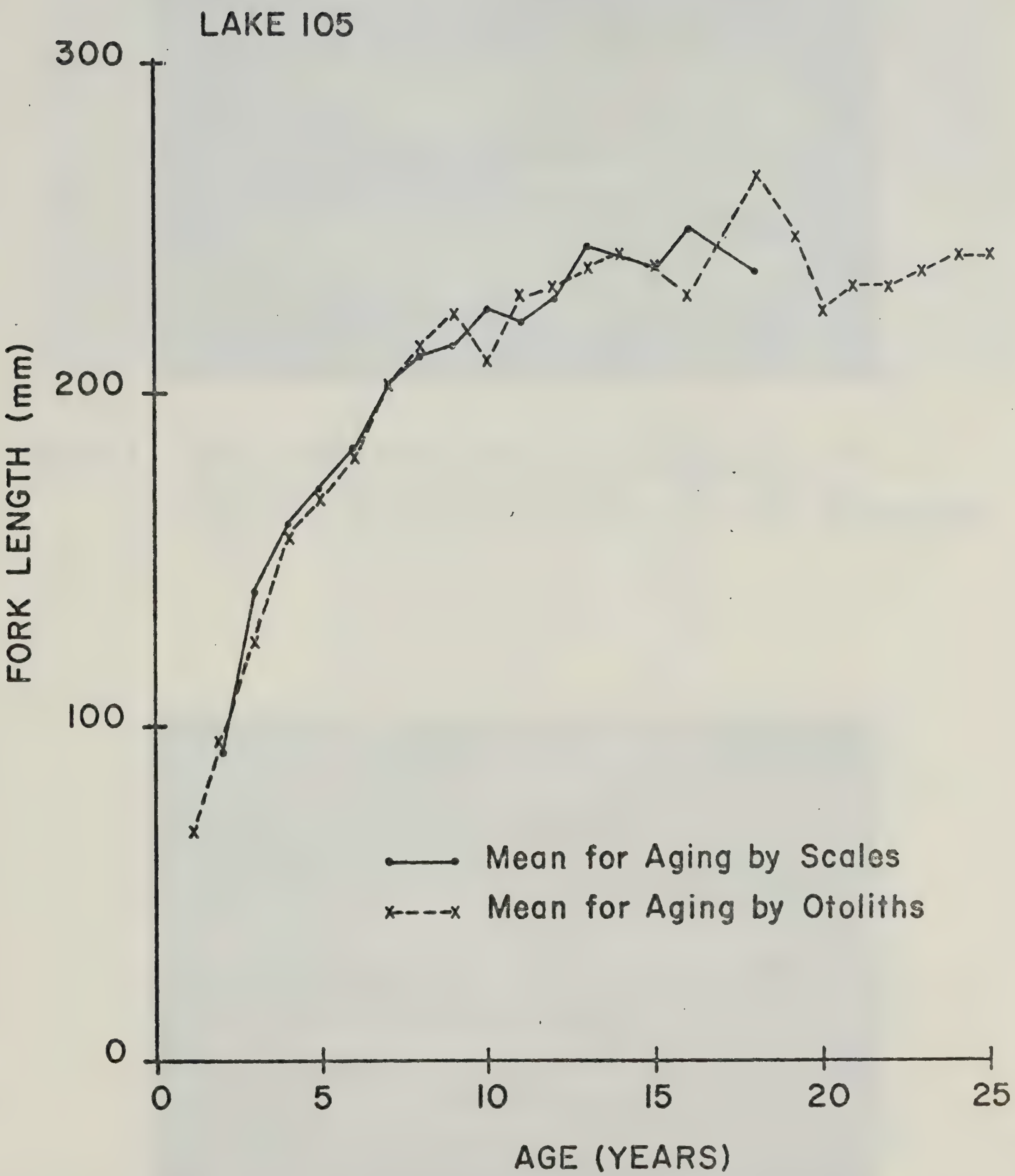


Figure 11. Age-length relationship, Lake 105: scales vs otolith ages.

Plate 9. Migratory Least Cisco (C. sardinella) from Beaufort Sea coast (bottom) were commonly captured in nets with arctic Cisco (C. autumnalis) (top).

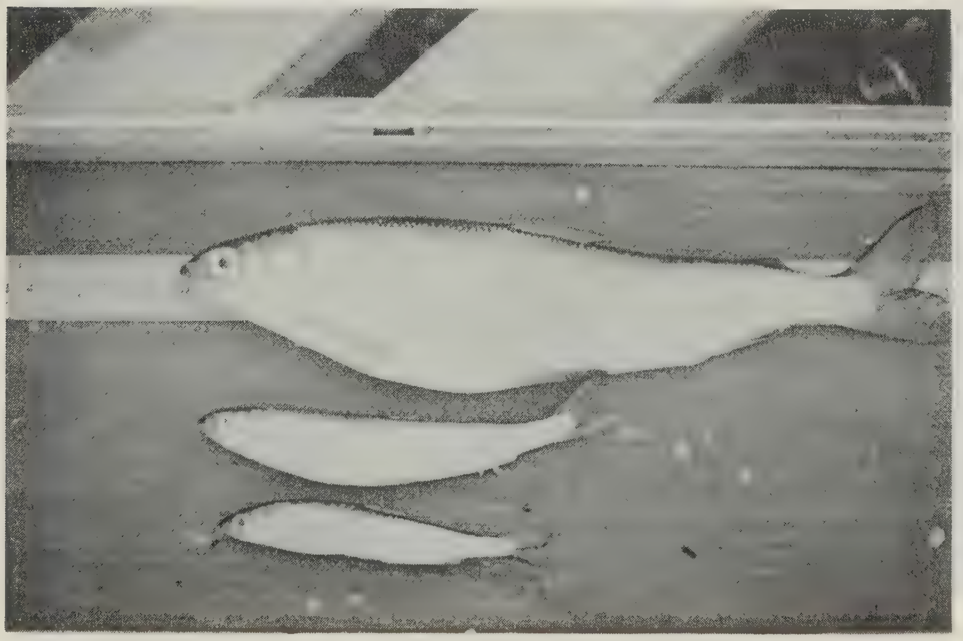
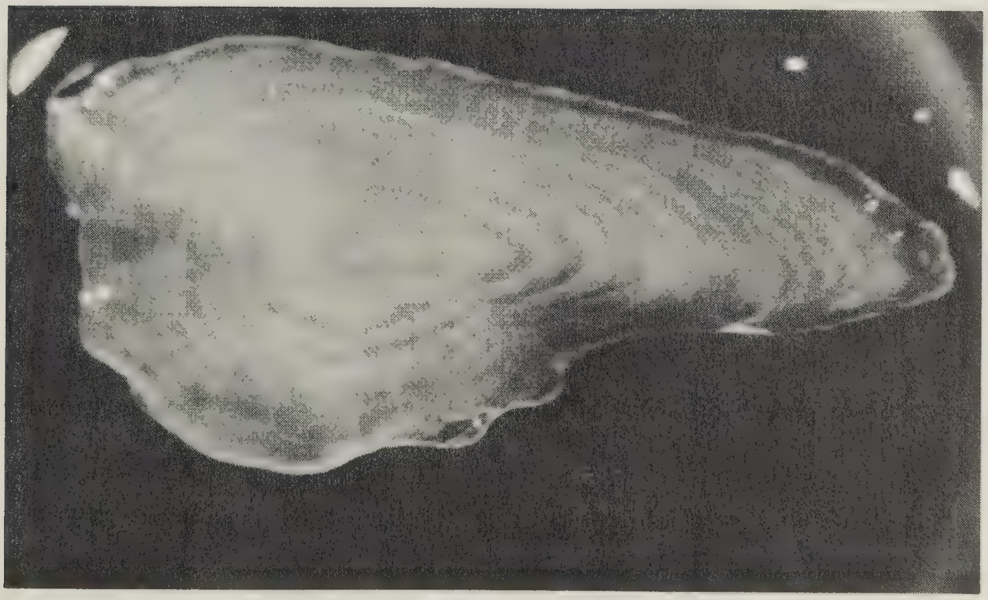


Plate 10. Top: mature "normal" least cisco from Trout Lake. Middle: immature "normal" least cisco from Trout Lake. Bottom: mature "dwarf" least cisco from Trout Lake.

A.

B.



C.

Plate 11. A. Trout Lake "normal":age=20, fork length=290mm.
B. Trout Lake "normal":age=21, fork length=296mm.
C. Lake 105: age=18, fork length=242mm.

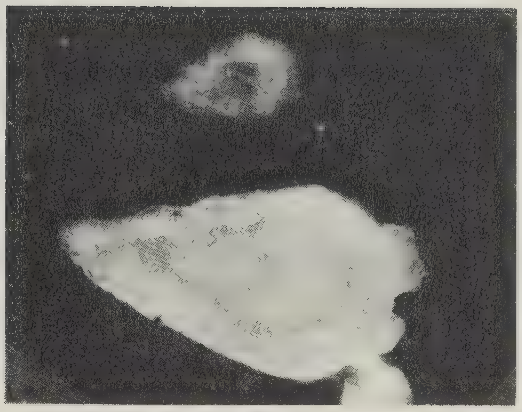


Plate 12. Otolith from a young-of-the-year from Trout Lake (top) and from a one-year-old captured in late August, 1973.

Life History Types and Growth Patterns

At an early date in the field collections, it became apparent that the least cisco in the study area exhibited a variety of differing life history forms. Since sampling was conducted in both freshwater and marine habitats it was not surprising to find some divergence in growth.

Least cisco that were taken in brackish waters along the Beaufort Sea coast were all assumed to be migratory since winter existence at the points of sampling would appear to be impossible due to sub-zero water temperatures (Walters, 1955) and the presence of thick ice near shore (personal observation). It is possible that the salinity of coastal waters would be at intolerably high levels since the freshening effect of freshwater inflow from North Slope rivers is drastically reduced in winter. No direct evidence of avoidance of high salinity seawater by least cisco could be found in the literature. However, on two occasions gillnets were set approximately 1/2 to 1 mile offshore in high salinity (30.0 parts per thousand-August 6, 1972) and moderate salinity seawater (17.0 ppt - July 23, 1973). In a total effort of 75 net hours, not a single individual of any species was captured.

It is believed that the migratory population of least cisco sampled at intervals along the coast of the North Slope represents dispersal of the large migratory population known to inhabit the Mackenzie River and its tributaries (Hatfield *et al* 1972). Some

evidence for this is provided in the section on spawning season (see page and Figures 29 and 30). Least cisco were commonly captured along with heavy catches of Arctic cisco (*C. autumnalis*) in brackish water areas (Plate 9).

A second type of migratory habit was encountered in the freshwater habitat. As mentioned previously, Peter Lake was netted at irregular intervals during the 1973 field season with gillnets of a variety of mesh sizes, including 1.3, 2.5, 3.8, 5.1 cm (3/4", 1", 1-1/2" and 2") stretched measure. Although the other species of coregonids in the lake were captured on every occasion (Appendix 1), *C. sardinella* were not captured until September 4, 1973. Gillnets set only 2 days previously failed to capture a single least cisco. About 82% (107/130) of the cisco captured on this date and thereafter were found to be mature, green, or mature and ripe in condition, indicating that this lake is used as a spawning area for a freshwater migratory population. This population has direct access to the Mackenzie Delta and Beaufort Sea via Holmes Creek (Figure 8), but it is not believed that these cisco leave fresh water. It is assumed that they reside in another lake in the system since the growth rate (age-length relationship - Figure 16) indicates similarity to other lake-resident populations studied.

Another life history type examined occurs in situations in which populations of least cisco become "land-locked" or do not have the opportunity of migrating into or out of the body of water in which they occur. As mentioned previously, this type of situation

appears to exist for two lake populations studied in the Yukon study area; in Trout Lake and Lake 105.

These lake-resident life history types are similar in that growth is considerably slower than that observed for anadromous populations (Figure 16). Although the brackish water least cisco attained a larger maximum size, they did not appear to achieve the longevity observed in lake-resident populations. Presumably, these observed differences in growth are due to differing food availability in the various habitats sampled, as well as differing physical parameters such as temperature, salinity, turbidity and light.

In the study areas, a major type of growth pattern was observed for populations of *C. sardinella* which is referred to as "dwarf". All other types of growth patterns are referred to as "normal" for the purposes of this report. Dwarf populations of least cisco have been reported only in a single instance in North America. This observation was made by McPhail and Lindsey (1970) and deals with dwarf populations in the Bristol Bay area of Alaska.

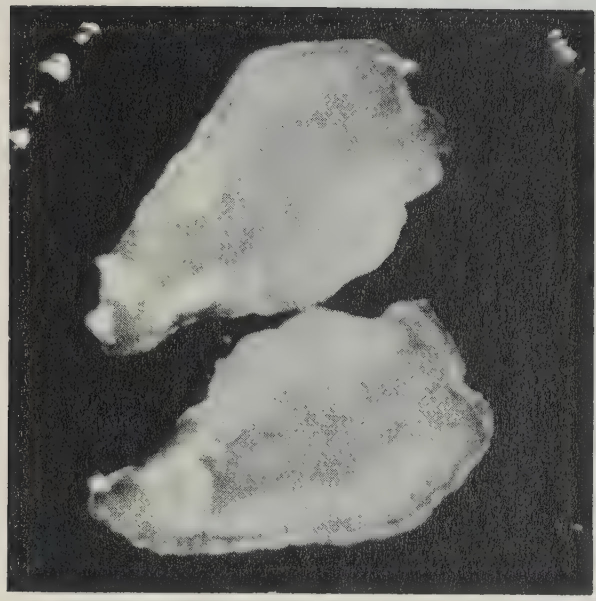
Dwarfism in coregonids has been described by a number of authors in Europe (Svärdson 1957) and North America (Kennedy 1943, Eschmeyer and Bailey 1955, Fenderson 1964, and McCart 1970). These authors have described situations in which both the normal and dwarf forms exist sympatrically in the same lake. Fenderson (1964) compared populations on the basis of age at maturity, growth rates, morphology and erythrocyte antigens to determine if the existence of the dwarf form was due to physiological variation within a homo-

geneous population, or if in fact the dwarf and normal groups represented discrete and isolated populations. He suggested that at least a partial barrier exists to gene flow between the two forms.

Two instances in which dwarf fish were found to be sympatric with normals were encountered in the study areas. In the Yukon area, Trout Lake was observed to contain a group of early-maturing individuals which seldom achieved a maximum age of fourteen years (Figures 14, 16). This dwarf population was virtually indistinguishable from similarly-sized immature individuals of the normal population on the basis of external morphology (Plate 10). Dissection revealed the advanced gonad development of dwarfs (Plate 15). They were commonly captured in the same localities and were found to be feeding on similar food items (page 105). The Trout Lake dwarf fish are presumed to be landlocked and non-migratory as is the normal population, for reasons stated previously.

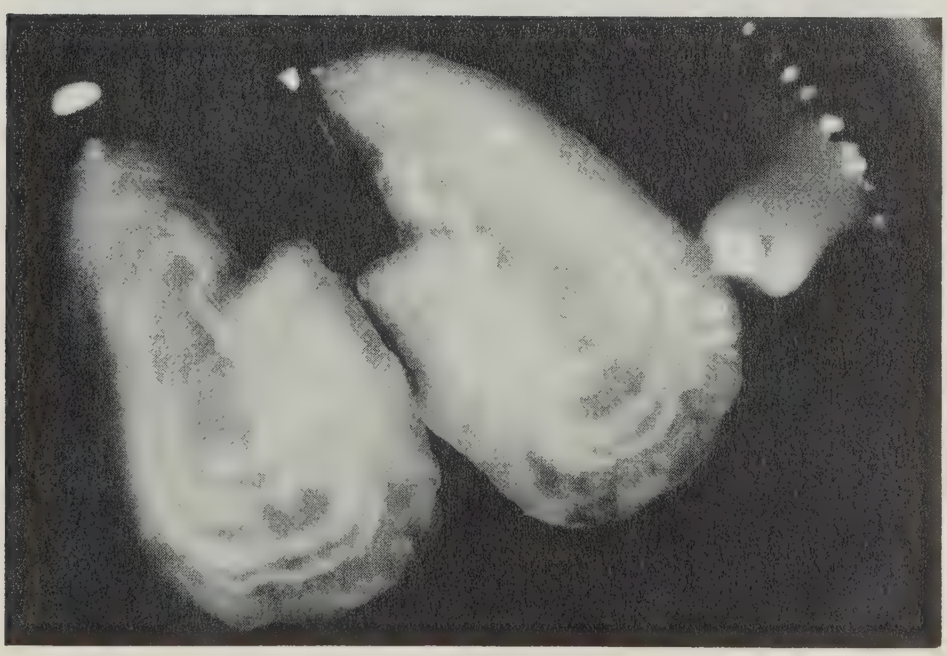
Plates 13 and 14 compare annulus patterns on otoliths from immature normal and mature dwarf least cisco of Trout Lake, and Peter Lake respectively. It may be observed that for a given length, the dwarf fish of Trout Lake may be twice the age of immature normals and that the dwarf cisco may attain considerable longevity at a relatively small size. Plate 14 illustrates the similarity of otolith annulus patterns for Peter Lake dwarf fish and normals although the two have greatly differing body size at a given age.

A second dwarf population was found to be present in Peter Lake in the NWT study area. These dwarf least cisco differ from the Trout Lake population in that they appear to be migratory and do not



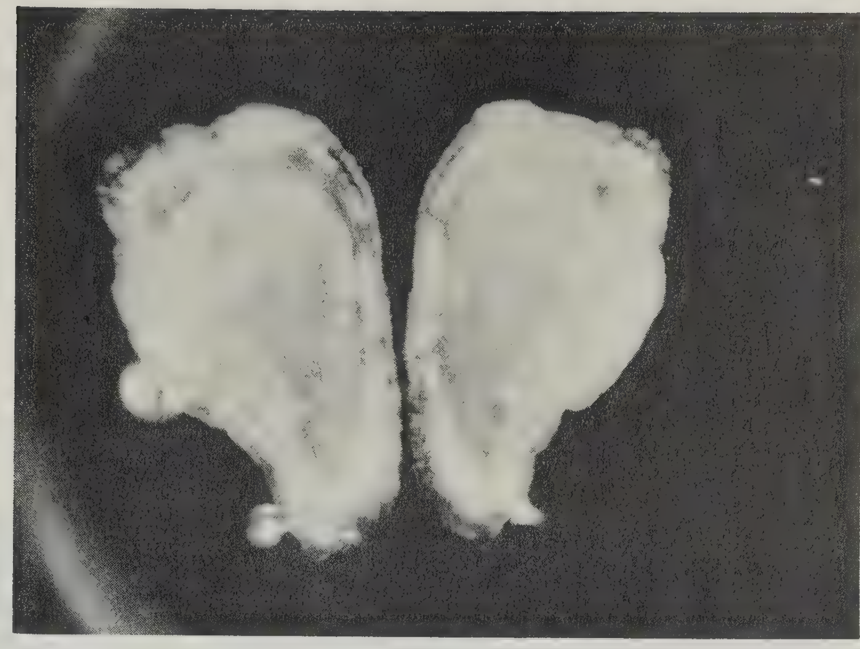
A.

B.

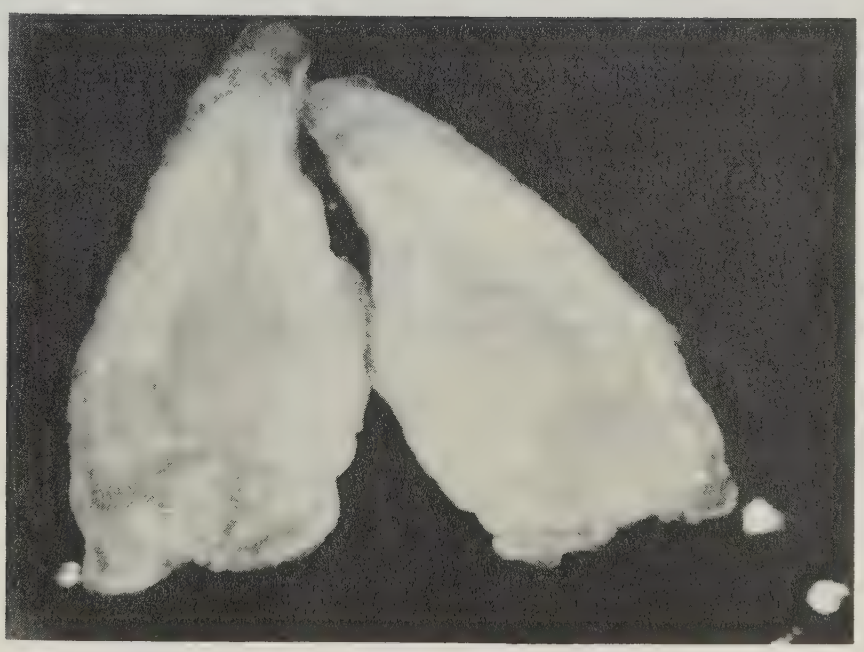


C.

Plate 13. A. Trout Lake immature "normal":age=2, fork length= 93mm. B. Trout Lake mature "dwarf":age=4, fork length=92mm. C. Trout Lake mature "dwarf":age=11, fork length=111mm.



A.



B.

Plate 14. A. Peter Lake mature "dwarf": age=3, fork length= 113mm. B. Peter Lake immature "normal": age=3, fork length= 138mm.

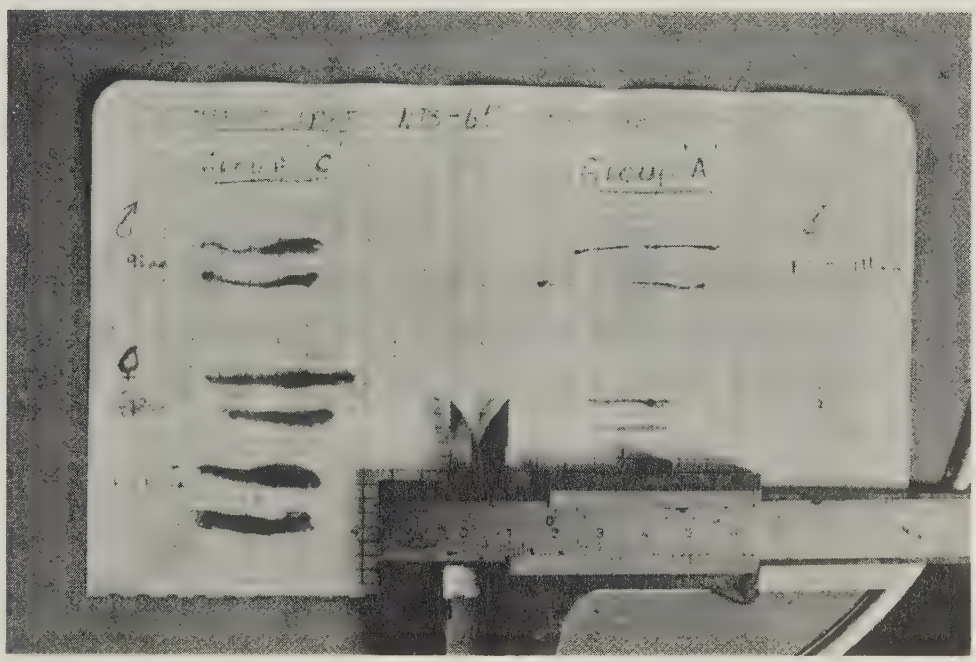


Plate 15. Comparison of similar size male and female gonads from "normal" immature (Group A) and "dwarf" mature (Group C) least cisco from Trout Lake,YT.

TABLE 3: Age-length relationship; Trout Lake normal and dwarf populations (sexes combined).

	Normal					Dwarf				
Age	N	$\bar{x}$	Range	SD	SE	N	$\bar{x}$	Range	SD	SE
0										
1	14	81.0	75-88	3.68	0.98					
2	62	87.03	75-111	7.28	0.93					
3	57	101.51	88-120	8.51	1.13	15	96.73	91-105	3.38	0.87
4	32	124.91	95-150	12.21	2.16	25	96.96	87-111	4.73	0.95
5	40	147.98	128-217	18.9	2.99	14	99.36	92-105	3.99	1.07
6	21	194.0	143-225	19.08	4.17	14	108.29	100-117	4.33	1.16
7	22	213.23	186-243	14.22	3.03	9	119.44	110-130	7.21	2.40
8	9	238.89	200-264	17.85	5.95	4	110.75	106-114	3.11	1.56
9	6	278.33	271-288	5.31	2.17	6	120.50	104-131	9.36	3.82
10	11	287.36	262-314	15.74	4.74	1	121.00	---	0	0
11	9	287.22	271-311	12.38	4.13	3	126.33	111-135	10.83	8.6
12	4	302.75	290-320	13.14	6.57	1	125.00	---	0	0
13	6	294.67	277-314	17.11	6.98	2	129.00	---	1.0	0.71
14	4	297.25	290-309	7.4	3.7	1	123.00	---	0	0
15	3	283.0	279-288	3.74	2.16					
16	1	340.0	---	0	0					
17	5	303.4	291-318	9.81	4.38					
18	4	290.5	273-302	11.63	5.82					
19	6	301.5	289-318	10.21	4.17					
20	8	299.13	284-322	11.86	4.19					
21	8	296.88	280-308	9.21	3.25					
22	4	291.75	272-304	11.97	5.99					
23	6	298.17	272-314	13.53	5.52					

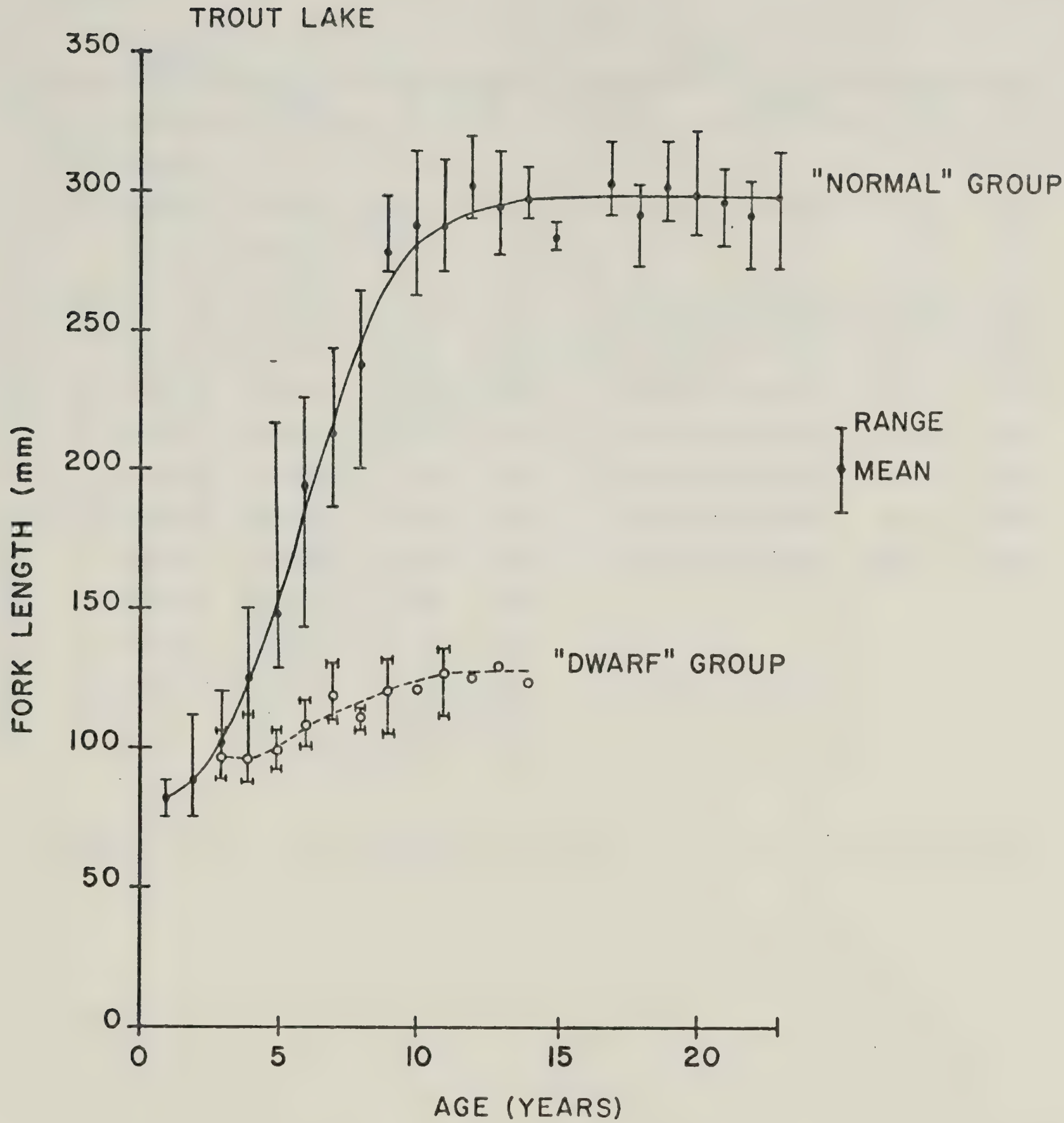


Figure 12. Age-length relationships, Trout Lake "normal" and "dwarf" populations (sexes combined).

TABLE 4: Age-length relationship; Peter Lake normal and dwarf populations, (sexes combined).

	Normal					Dwarf				
Age	N	$\bar{x}$	Range	SD	SE	N	$\bar{x}$	Range	SD	SE
2	2	120.0	---	0	0	0	-	---	-	-
3	7	149.14	125-177	18.56	7.0	9	121.0	113-135	7.72	2.57
4	2	170.0	168-172	2.0	1.42	0	-	----	-	-
5	15	203.73	186-216	7.78	2.01	6	124.67	118-131	4.75	1.94
6	7	216.86	193-232	13.25	5.0	3	127.33	125-128	1.7	0.98
7	13	232.08	216-247	8.35	2.31	8	126.63	118-132	4.9	1.73
8	17	229.71	217-252	9.71	2.36	8	133.88	125-142	6.19	2.19
9	3	229.33	221-236	6.24	3.61	2	145.5	143-148	2.5	1.77
10	7	239.43	232-247	5.58	2.11	2	149.0	144-154	5.0	3.55
11	3	238.33	233-242	3.86	2.23	2	130.0	120-140	10.0	7.09
12	3	246.33	239-251	5.25	3.03					
13	8	240.75	231-252	6.46	2.28					
14	6	249.67	244-258	5.12	2.09					
15	10	249.1	235-267	9.96	3.15					

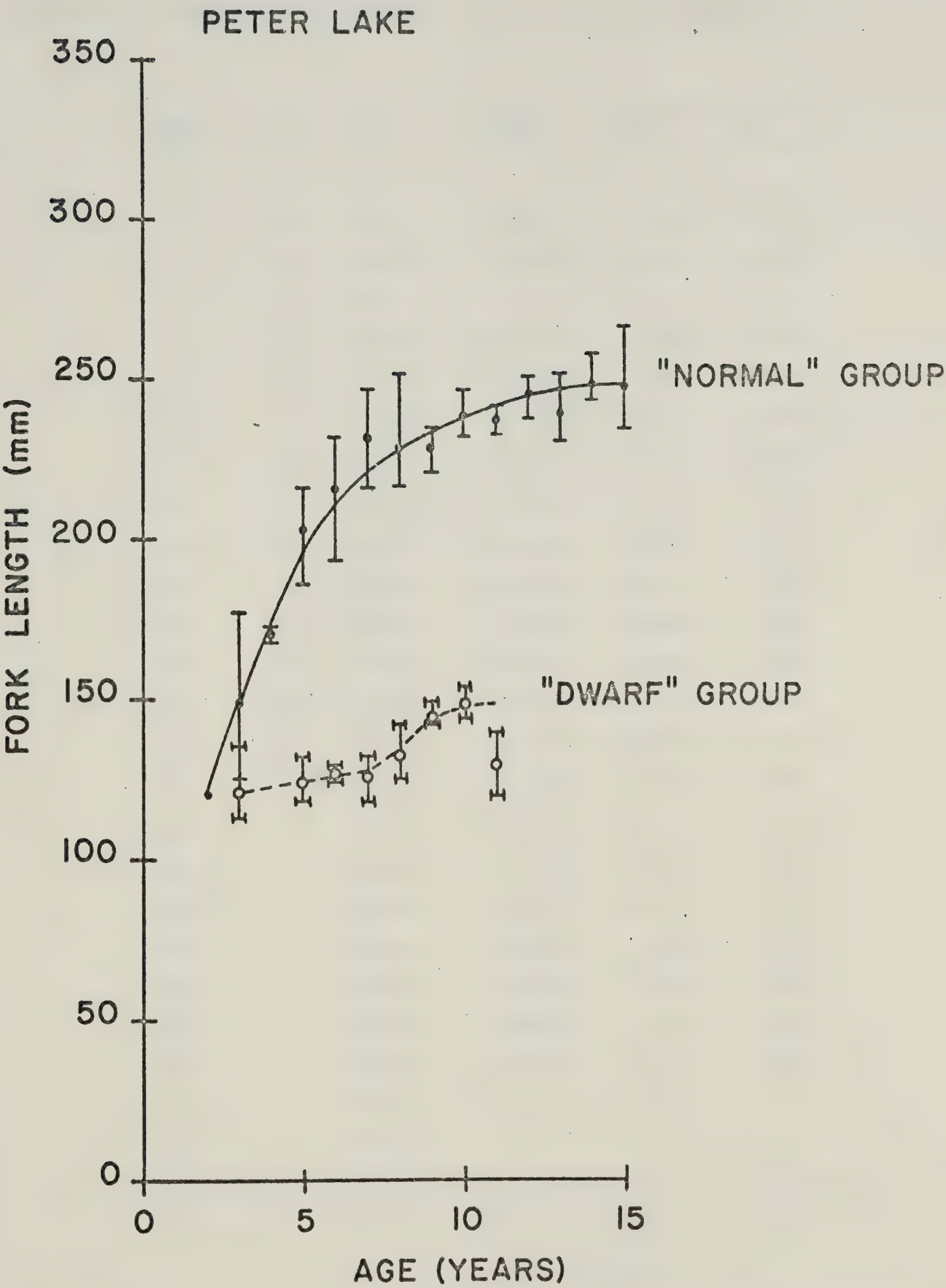


Figure 13. Age-length relationships, Peter Lake "normal" and "dwarf" populations (sexes combined).

TABLE 5: Age-length relationship; Lake 105 (Sexes combined).

Age	N	$\overline{x}$	Range	SD	SE
0					
1	20	66.7	59-72	3.26	0.73
2	45	93.89	87-105	4.13	0.62
3	1	125	---	-	-
4	52	158.29	130-179	7.68	1.07
5	12	167.08	147-180	7.87	2.27
6	12	180.67	148-205	18.13	5.24
7	10	201.3	172-215	12.41	3.93
8	3	215.33	208-225	7.13	4.12
9	8	225.5	218-236	6.26	2.21
10	2	210.0	207-213	3.0	2.13
11	9	229.22	212-250	10.43	3.48
12	13	231.54	211-251	9.48	2.63
13	12	238.92	226-245	5.57	1.61
14	7	240.71	222-257	12.66	4.78
15	4	238.5	211-259	17.34	8.67
16	7	232.14	209-263	16.18	6.11
18	3	267.67	221-311	36.82	21.28
19	4	246.5	220-273	23.26	11.63
20	4	226.5	223-232	3.35	1.68
21	4	232.75	214-262	17.85	8.93
22	3	232.67	230-236	2.49	1.44
23	2	236.5	236-237	0. 5	0.35
24	1	242.0	---	-	-
25	1	242.0	---	-	-

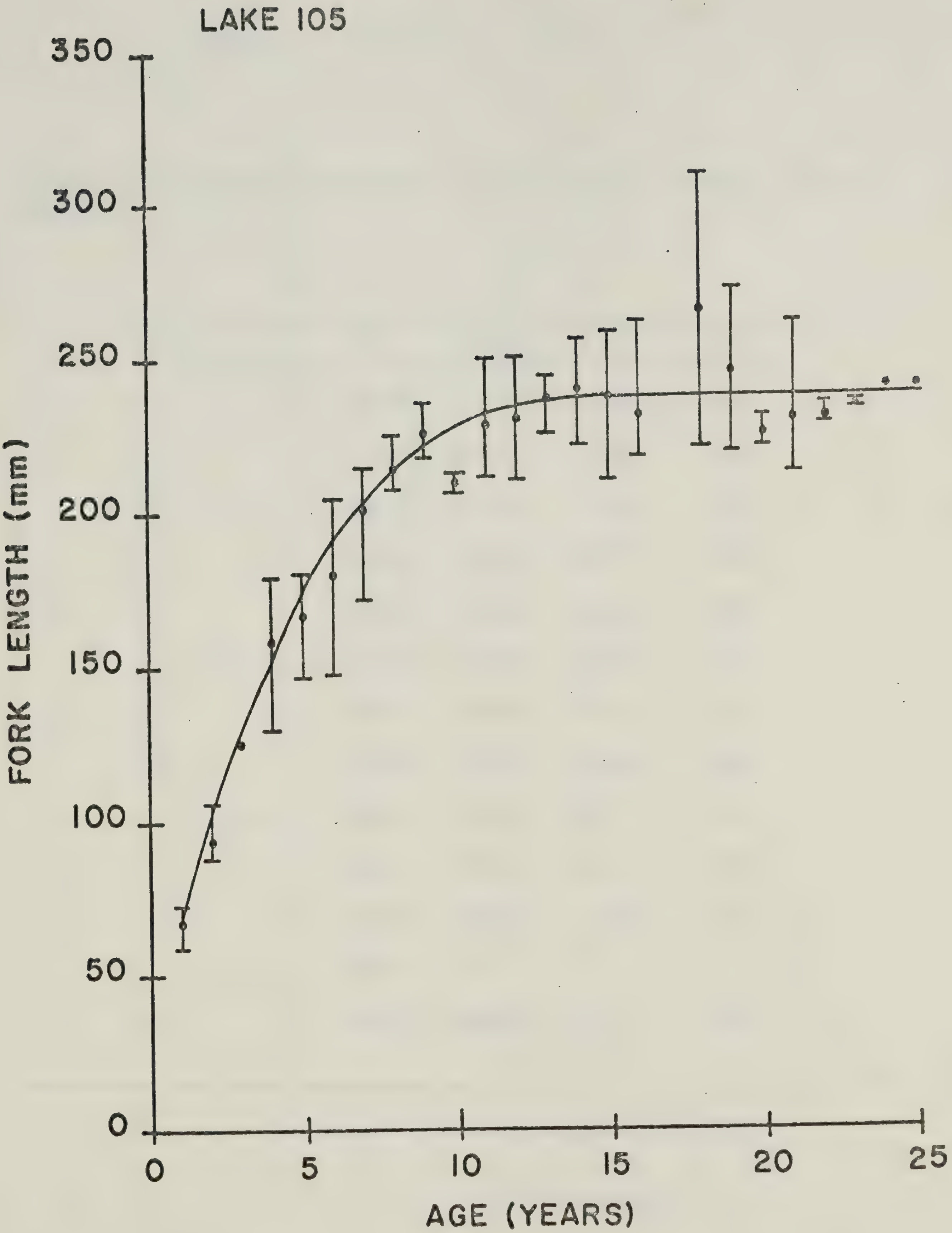


Figure 14. Age-length relationship, Lake 105 (sexes combined).

TABLE 6: Age-length relationship, Brackish water stations (sexes combined).

Age	N	$\bar{x}$	Range	SD	SE
1	4	89.75	82-91	1.09	0.55
2	6	114.0	100-127	9.59	3.91
3	28	186.53	165-199	9.66	2.34
4	31	213.81	180-243	20.34	3.65
5	26	232.19	201-271	18.43	3.61
6	25	258.52	231-296	16.04	3.21
7	9	274.0	245-306	19.52	6.51
8	7	278.86	253-317	20.34	7.68
9	9	296.33	280-319	13.9	4.63
10	7	308.0	292-322	11.4	4.30
11	9	317.33	303-337	9.43	3.14
12	1	320.0	---	-	-
13	6	320.33	308-334	10.37	4.23

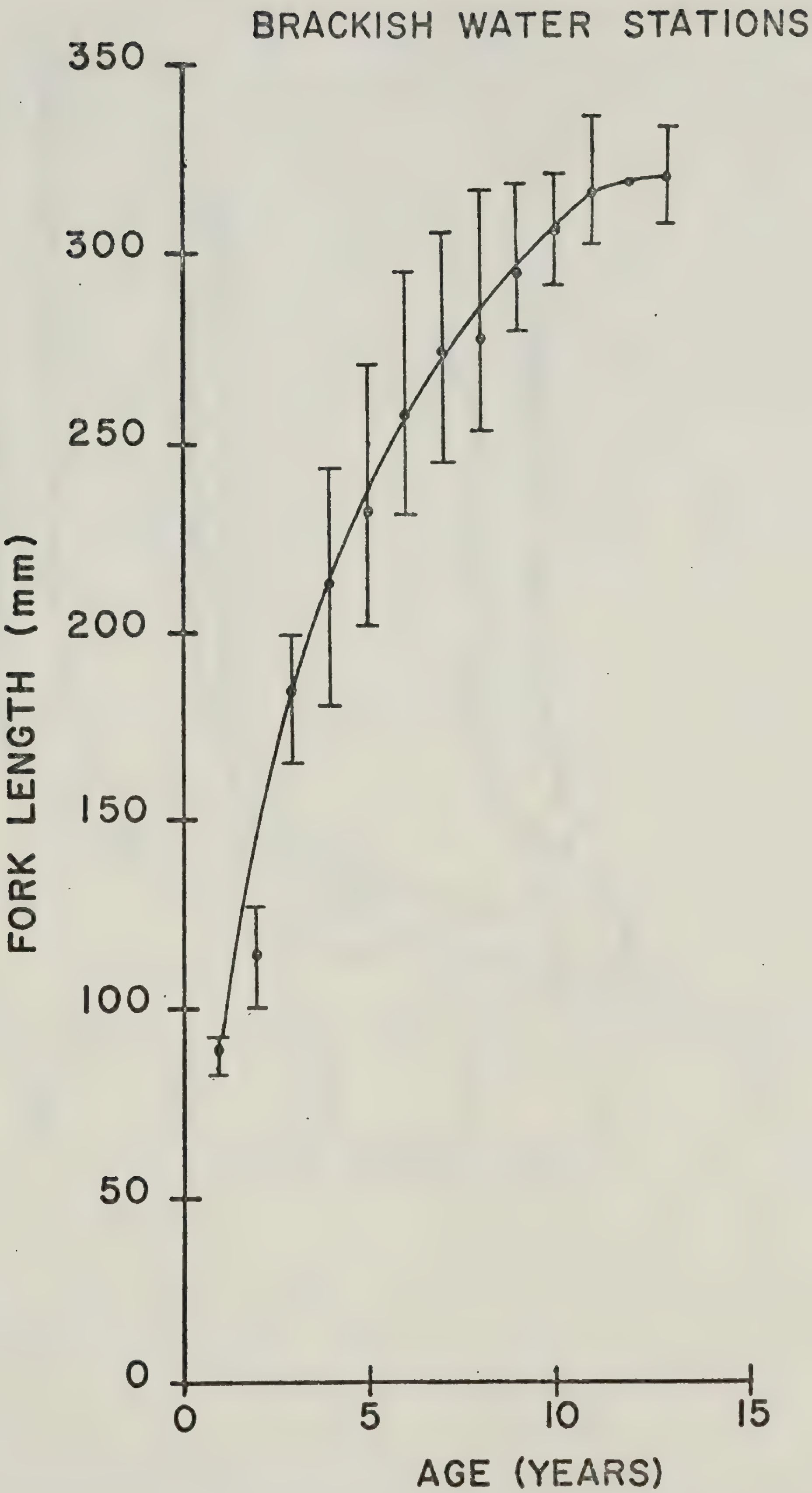


Figure 15. Age-length relationship, Brackish water stations (sexes combined).

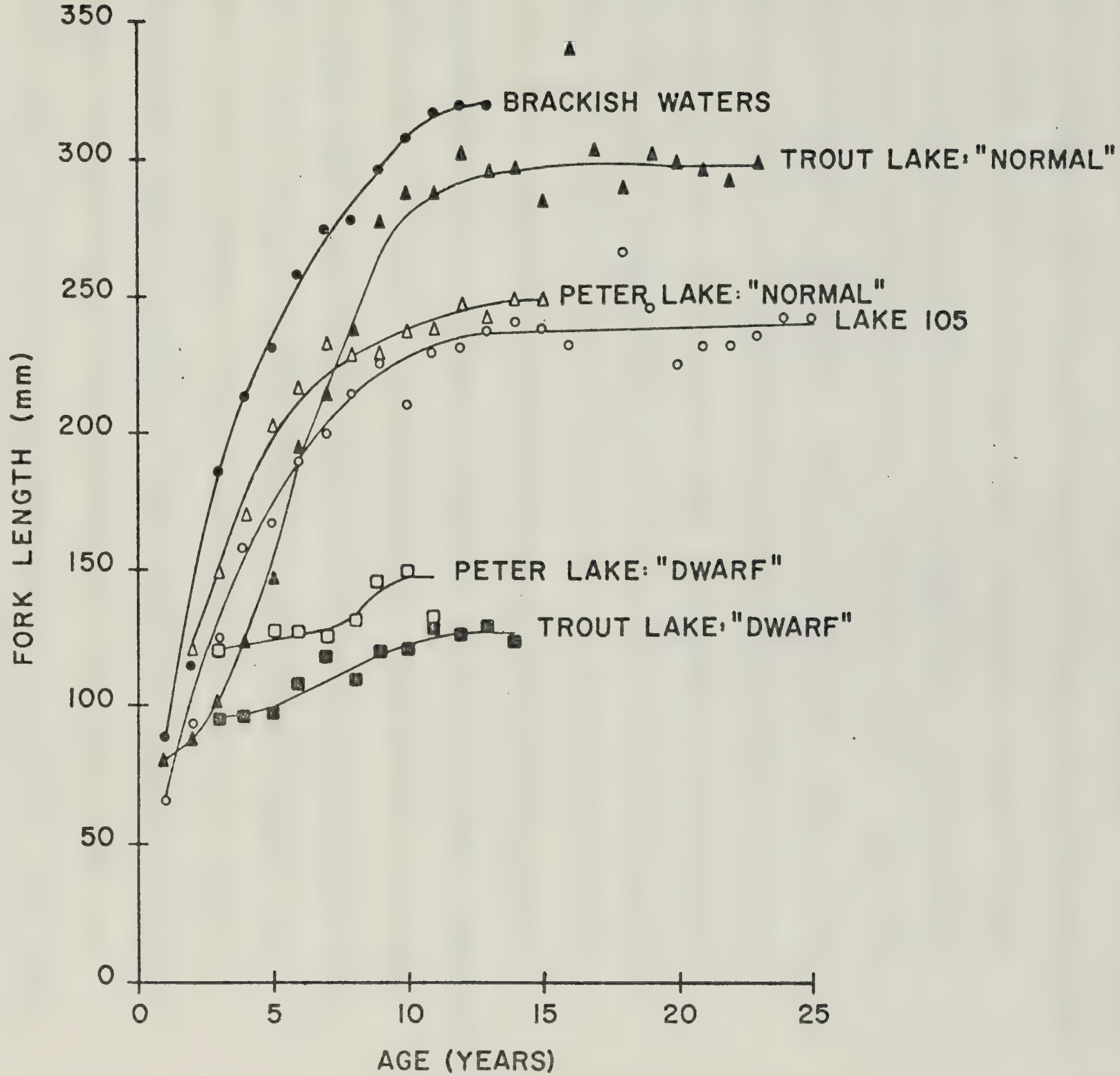


Figure 16. Age-length relationships, compared.

reside in Peter Lake during the summer months. It appears that these fish migrate from an unknown area (probably another lake in the Holmes Creek drainage) into the lake to spawn. It is not known if these dwarf fish remain in the lake to overwinter. However, during a 24 hour gillnetting (192 gillnet hours) on September 20 - 21, 1973, only a single dwarf specimen was captured. The dwarf fish may leave Peter Lake to overwinter in another lake or may move into deeper water after spawning. The Peter Lake dwarf population differs from the Trout Lake population in that a larger body size appears to be attained at any given age. Maximum length observed in the Peter Lake population was 154 mm. However, this is considerably lower than that attained by the Trout Lake dwarf population which appears to attain greater longevity than Peter Lake dwarf population (11 *vs* 14 years, respectively)(Figures 12, 13, 16). Peter Lake dwarf *C. sardinella* were found to attain gonad ripeness and begin spawning as early as September 10, 1973. At this time, more than 90% of the individual females were either ripe, or spawned-out, whereas 9 days previously, no dwarf females were ripe in condition. Trout Lake dwarf fish do not appear to begin spawning until late September since less than 1% of the females taken on September 12 and September 26 were ripe. Peter Lake dwarf fish were similar to those of Trout Lake in that they were indistinguishable from immature normal least cisco in their external morphology, and were commonly captured in the same areas as normal least cisco.

Age-length data were analyzed and compared on the basis of sex for each location using t-tests. Significant differences between

males and females occurred in only a few isolated cases in which sample sizes were small. In most cases, differences between sexes in the mean length at a given age were not significant ($p > .05$) therefore data were combined for this analysis.

Of the six populations and sub-populations described, least cisco in brackish waters appear to exhibit the most rapid growth during the first 5 years of life (Figure 15, Table 6). Growth does not become asymptotic until approximately age 12, and of the 4 normal populations sampled, brackish water, migratory least cisco were found to attain the lowest maximum age (13).

Of the 3 normal lake resident populations examined during this study, Trout Lake least cisco were found to attain the largest maximum size (339 mm fork length). A typical lake-resident growth curve is exhibited by this population in that growth is rapid during the early years of life prior to attaining sexual maturity. Thereafter, annual growth increments become progressively smaller (Figure 12, Table 3). The asymptotic length of normal least cisco from Trout Lake is approximately 300 mm (Figure 12).

The two remaining normal freshwater populations studied, Lake 105, YT and Peter Lake, NWT, appeared to exhibit similar growth rates during the earlier years of life (Figure 16). However, in spite of the fact that the asymptotic growth phases are very similar (Lake 105, approximately 240 mm; Peter Lake, approximately 250 mm fork length) Peter Lake normal least cisco have a much shorter life span. (Figures 13, 14, Tables 4, 5). Lake 105 cisco were aged as high as

25 years, whereas the maximum age observed for Peter Lake was 15 years. This shorter life span of migratory least cisco appears to be characteristic in the study areas.

The age-length relationships for dwarf populations of least cisco examined illustrate the comparatively slow growth of these populations (Figure 16). Since dwarf fish could be identified only by their advanced gonad development, the age-length relationship does not include data for the period in which these fish were immature and therefore were indistinguishable from immature normal cisco less than three years of age.

Growth in length by dwarf fish is minimal after sexual maturity (Figure 16). Peter Lake dwarf fish are consistently larger than those of Trout Lake of the same age (Figure 16). Peter Lake dwarf fish are believed to be migratory and the observed shorter life span is consistent with the same observation in migratory normal populations of least cisco (Figure 16). It is possible that this results from increased exposure to predators during migration. No data could be obtained during these studies to substantiate this.

The observed differences in growth patterns for the populations studied may be related to competition for food and space. Brackish water least cisco exhibit the best growth, presumably since food is abundantly available to them during the summer months along the Beaufort Sea coast. In Trout Lake, the least cisco was, on all occasions, the most abundant species in gillnet and seine net catches. The next most abundant species captured in the lake was Arctic gray-

ling. Comparison of grayling feeding data (deBruyn and McCart, 1973) with stomach content analysis for least cisco (page 103) indicates little interspecific competition for food. Although this study did not allow sufficient time for large-scale benthic and planktonic studies, it seems probable that Trout Lake must possess a relatively richer food base than Lake 105 since a comparatively larger body size was attained by Trout Lake least cisco. In Lake 105, least cisco were extremely abundant and appeared to be the dominant species present, over a much smaller population of Arctic grayling and an even smaller population of lake trout. Intraspecific competition and low utilization by the predator species (lake trout) may have combined here to produce stunting of the least cisco population. Similar situations have been described by others (Alm 1959, Lindström and Nilsson 1962) for coregonid populations in Europe and North America.

Since it is not known where the migratory population captured in Peter Lake spends the majority of the summer season, it is difficult to know what conditions have produced the comparatively small body size. It appears, however, that the areas they occupy must not be as favourable for the growth of least cisco as the area occupied by the brackish water, migratory population studied.

Growth of Young of the Year

The capture of least cisco young-of-the-year proved to be a difficult task in most sampling areas. The following collection methods were employed: minnow traps (wire mesh), Faber Net (Faber, 1968) (a large plankton net towed or pushed by a boat), trawling with seine nets behind and boat and beach seining using various lengths of seine net. Of all these methods only beach seining in Trout Lake and Lake 105 proved successful. Fry did not appear to be abundant in nearshore waters at most times (Table 14) and also the shore morphology of Lake 105 and Peter Lake with their rapid increase in depth caused some difficulty in capturing fry. These difficulties are reflected in the data obtained (Figure 17) and it may be seen that the majority of samples were obtained during the 1973 field season.

Although the time of hatching of least cisco fry is unknown, extrapolation of growth curves for Trout Lake and Lake 105 fry suggests the time of emergence is approximately mid-June, when the fish have attained a length of approximately 8 to 10 mm. A sample of 100 *Coregonus* sp. fry from Peter Lake, NWT (some of which are undoubtedly *C. sardinella*) on June 20, 1973 had a mean length of 11.13 mm. On July 27, 1973 the *Coregonus* sp. fry were captured in the same locality in Peter Lake (Figure 9) and were found to have increased in length to a mean of 15.7 mm (N=37).

Young-of-the-year least cisco from Trout Lake appear to grow at a rate only slightly greater than that observed in Lake 105. A

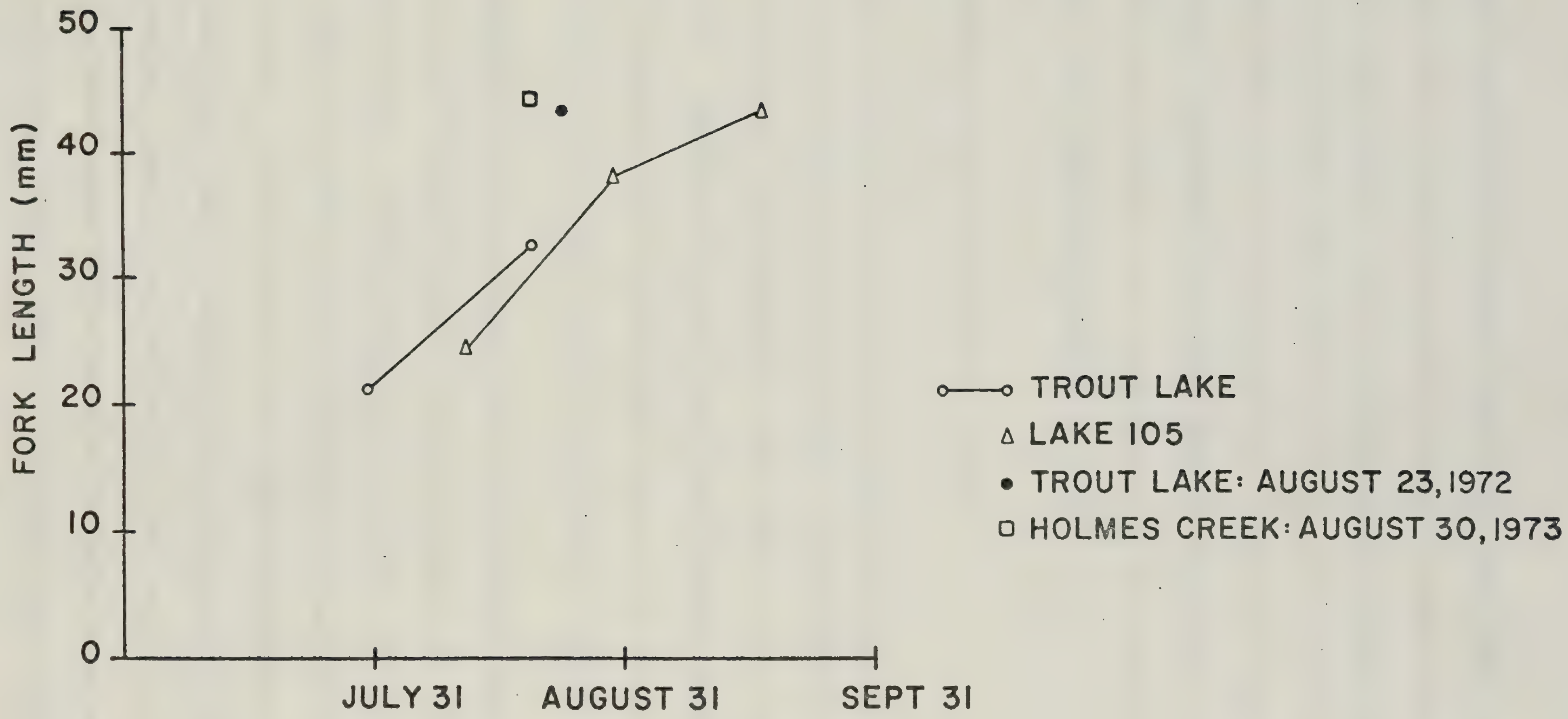


Figure 17. Least cisco fry growth, 1972-1973.

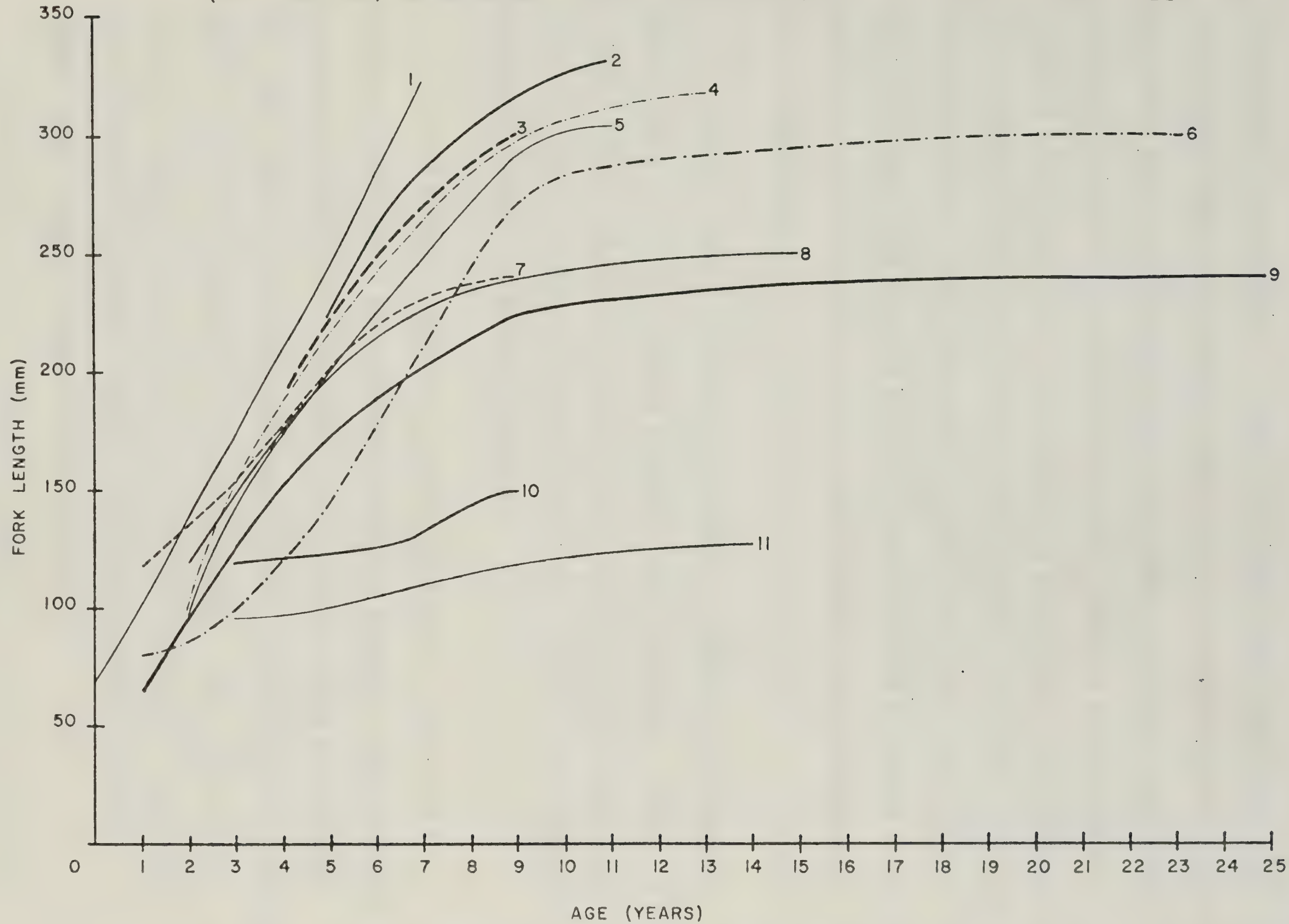
single sample obtained from Holmes Creek in mid-July indicates that fry of least cisco in this system may utilize the stream habitat to some extent. They appear to have a significantly greater growth rate than fry captured in the North Slope study area in the 1973 growth season. The growth rate of fry may be highly variable from year to year as Figure 17 indicates. Mid-July samples taken only 5 days apart, in succeeding years indicate that conditions for fry growth in Trout Lake may have been considerably better in 1972.

Comparison with Growth in Other Areas

As discussed previously, the only other observations on growth of least cisco were reported by Cohen (1954) in Point Barrow, Alaska, Hatfield *et al* (1972) in the Mackenzie River, NWT and most recently by (Kogl *et al)* (1972) and Alt and Kogl (1973) for the Colville River in Alaska. A comparison of age and growth reported by these authors with the results of the present study is presented in Figure 18.

Populations which were associated with brackish waters or major river systems and which are believed to be migratory, all exhibited similar growth curves. These include Colville River, Point Barrow (Type "M", Type "F" - Cohen, 1954), Mackenzie River and Yukon North Slope least cisco. All fish except those captured during the present study and those taken from the Mackenzie by Hatfield *et al* (1972) were aged using scales. Cohen's Type "M" and Type "F" least cisco were broken up into these groups on the basis of differing annulus patterns observed on the scales (Cohen, 1954). This author felt that "F" type cisco remained in fresh water and the "M" type migrated into fresh

Figure 18. Comparison with growth in other areas. 1. Alt and Kogl, 1973 (Colville R.) 2. Hatfield et. al., 1972 (MacKenzie R.) 3. Cohen, 1954, Type 'F' (Pt. Barrow) 4. Brackish water stations (YT) 5. Cohen, 1954, Type 'M'



6. Trout Lake "normal" 7. Cohen, 1954, Type 'X' 8. Peter Lake "normal" 9. Lake 105 (YT) 10. Peter Lake "dwarf" 11. Trout Lake "dwarf".

water from a nearby lagoon. Since the growth curves for these two types do not differ significantly from those observed in other marine migratory forms, it is likely that this author has merely described a situation in which two rearing areas may be involved which produce distinct annulus patterns. These separate populations have subsequently come together into Ikroavik Lake and probably move freely into and out of the lake to the nearby Elson Lagoon during the summer months. Thus it is felt that Cohen's Type "F" and "M" should be lumped together and referred to as having a single brackish-water migratory life history type.

Cohen's Type "X" least cisco appear to exhibit the typical growth curve of a lake-resident non-migratory population. Growth in length becomes asymptotic at approximately 230 mm, and had aging been conducted using otoliths, a growth curve very similar to the Lake 105 population would probably have resulted.

It is believed that the partial growth curve presented by Hatfield *et al* (1972) for the Mackenzie River probably represents the spawning population of which least cisco captured along the Beaufort Sea coast during the present study are members. Hatfield *et al* (1972), report an upstream migration primarily of mature, green individuals during the summer months while the results of the present study indicate a decrease in number of mature, green individuals from mid-summer until late fall (Figure 30 and Page 96).

Weight-Length Relationships

The relationship between weight and length is described by the expression: Log W = log a+b (log L), where log a is the y intercept and b is the regression coefficient. Regression plots often differ when different stocks within a species are compared. Such information is useful as an index of growth and production for commercially harvested species (Ricker, 1968).

Weight-length relationships were compared between populations to see whether any significant differences were present. Intra-population variation was also examined. The data typically showed a high degree of correlation ($r>0.7000$), thus stratified sub-samples of length-weight data were used in calculation of regression lines. Significance of differences between slope and elevation (intercept) of regression lines was tested using analysis of covariance and comparison of F-ratios (Sokal and Rohlf, 1969).

Comparisons between sexes and mature and immature individuals revealed that in most cases length-weight regressions did not differ significantly ($p>.05$) in slope or elevation. Brackish water least cisco exhibited the most intra-population variation, probably since this group consisted of a non-homogeneous mixture which may have originated from a number of different rearing areas.

In order that inter-population differences could be examined, samples were combined and compared on the basis of sex. If no

significant difference was detected within each population, sexes were combined and a single regression equation was derived for the population (Table 7). Regression data are graphically presented in Figure 19.

Among normal populations, Lake 105 least cisco differed most commonly in slope of length-weight regression lines from the other populations with which it was compared. This is understandable since this population was found to be the slowest growing of the normals in the study area (page 54 and Figure 16).

Peter Lake normals commonly differed from other populations in the elevation (y - intercept) of length-weight regression lines. This result may have been biased somewhat by the fact that Peter Lake cisco were almost exclusively in an advanced state of gonad development. Other population regression lines were calculated from data taken from both immature and mature individuals.

Dwarf populations did not commonly differ significantly in slope when compared with other populations, however, significant differences in elevation of regression lines were found in many inter-population comparisons. (Table 8).

TABLE 7: Weight-length regression formulae

Trout Lake "normal" (sexes combined)

Log W=3.0955 (Log L)-5.2447, r=0.9946, N=100

Peter Lake "normal" (sexes combined)

Log W=2.5636 (Log L)-3.9616, r=0.9320, N=50

Lake 105 (sexes combined)

Log W=3.1070 (Log L)-5.2436, r=0.9972, N=50

Brackish waters; ♂:

Log W=2.9477 (Log L)-4.9518, r=0.9864, N=35

Brackish waters; ♀:

Log W=1.7744 (Log L)-2.1115, r=0.8198, N=35

Trout Lake "dwarf"; ♂:

Log W=2.9156 (Log L)-4.9633, r=0.9609, N=50

Peter Lake 'dwarf' (sexes combined)

Log W=2.4135 (Log L)-4.0119, r=0.9314, N=40

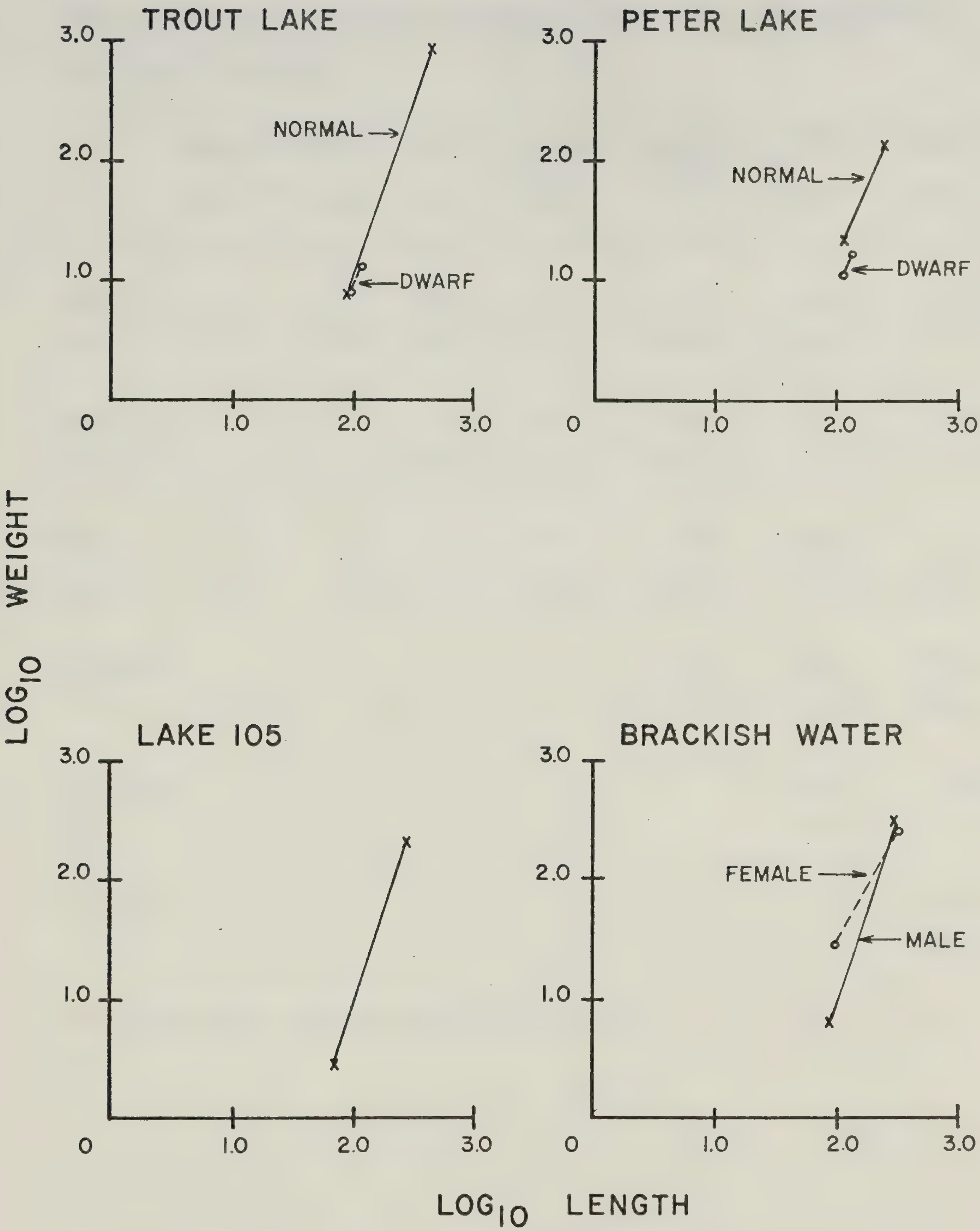


Figure 19. Length-weight relationships.

TABLE 8: Weight-length relationships ANCOVA. n.s.=not significant *=significant at .05 level, **=significant at .01 level for slope and (elevation).

	Trout L. "N"	Peter L. "N"	Lake 105	Brackish Water ♂	Brackish Water ♀	Trout L. "D"	Peter L. "D"
Trout L. "N"		** (*)	n.s. (n.s.)	n.s. (*)	** (n.s.)	n.s. (n.s.)	n.s. (**)
Peter L. "N"			** (n.s.)	n.s. (**)	n.s. (n.s.)	n.s. (**)	n.s. (**)
Lake 105				** (*)	** (n.s.)	n.s. (*)	* (**)
Br.water ♂					n.s. (**)	n.s. (n.s.)	n.s. (n.s.)
Br.water ♀						n.s. (**)	n.s. (**)
Trout L. "D"							n.s. (n.s.)

Maturity Relationships

Maturity Criteria and Frequency of Spawning

The rationale for judging state of maturity is presented on Page 34.

At an early point in field studies it was observed that a small proportion of mature individuals of both sexes appeared to be lagging behind the majority in gonad development. As the spawning season approached, this difference in gonad condition became more apparent and it became obvious that a portion of the populations studied were not capable of spawning in consecutive years. Such individuals were assigned a condition factor of "WS" (meaning will not spawn in the year of capture). The abundance of such individuals in a resting stage in the least cisco populations studied is presented in Tables 9 and 10. Several trends may be noted:

1) among normal lake-resident and freshwater migratory populations studied, WS individuals were most common among Lake 105 cisco. A reflection of intraspecific competition for food may have produced the observed stunting of growth.
2) the WS condition was most commonly assigned to mature females in all populations examined. This may be due to a greater energy requirement for the production of eggs. However, this result may be biased in favour of females due to the relatively lesser degree of gonad development in males and the resultant difficulty in determining condition.

3) a large percentage of individuals in the older year classes were judged to be WS in condition; possibly indicating a reduced ability in older fish to produce sex products in successive years.

4) the majority of individuals captured in brackish waters were judged to be either immature, or if mature, then WS in condition. This provides further evidence for the theory that the Yukon North Slope brackish water areas are utilized in the summer months primarily by immature and non-spawning individuals as a feeding and recuperation area.

5) The "prime" spawning years among dwarf least cisco of Trout Lake are the first four years after maturity is reached. Subsequently there appears to be high mortality and decrease in the frequency of repeat spawning among survivors.

Cohen (1954) and Wohlschlag (1954) make no reference to whether or not spawning occurs every year among mature least cisco of Point Barrow. Alt and Kogl (1973), indicate the occurrence of non-spawning mature individuals captured in the Colville River. No mention of state of maturity is made in reports by Hatfield *et al* (1972) on Mackenzie River least cicso. However, fish captured in the same areas in 1972 by Stein *et al* (1973) indicate that the least cisco were on a spawning migration up the Mackenzie River and its delta tributaries. Numerous reports of alternate-year spawning in Arctic populations of salmonids and coregonids are present in the literature (Kennedy, 1954; Miller and Kennedy, 1948; Rawson, 1961; McCart *et al*, 1972; etc.).

TABLE 9: Age, sex and maturity structure: Normal LSCS

	Trout Lake				PeterLake				Lake 105				Brackish Waters			
Age	% Male	% Mature	% "WS"	N	% Male	% Mature	% "WS"	N	% Male	% Mature	% "WS"	N	% Male	% Mature	% "WS"	N
0		0	-				-	0		0	-				-	0
1	42.9	0	-	14			-	0		0	-	20	100	0	-	4
2	62.9	0	-	62		0	-	2	62.2	0	-	45	50	0	-	6
3	66.7	0	-	57	57.1	0	-	7	100	0	-	1	60.7	0	-	28
4	78.1	0	-	32	100	0	-	2	50	0	-	52	70.9	0	-	31
5	55.0	0	-	40	60	♂ 22.2 ♀ 0	0	15	66.6	0	-	12	57.7	♂ 26.6 ♀ 9.9	0	26
6	40.9	o 0 ♀ 8.3	0	21	28.6	50 , 40	0	7	58.3	♂ 32.8 ♀ 0	0	12	68.0	41.2 62.5	0	25
7	63.6	7.1 12.5	0	22	61.5	100	0	13	50	40 60	0	10	12.5	100 77.8	0	9
8	77.7	14.3 50	0	9	64.7	100	♂ 0 ♀ 16.7	17	100	100	0	3	71.4	100	♂ 40 ♀ 50	7

TABLE 9: Continued

	Trout Lake				Peter Lake				Lake 105				Brackish Waters			
Age	% Male	% Mature	% "WS"	N	% Male	% Mature	% "WS"	N	% Male	% Mature	% "WS"	N	% Male	% Mature	% "WS"	N
9	50.0	100	0	6	33.3	100	0	3	50	100	♂ 20 ♀ 0	8	44.4	100	25 80	9
10	18.2	100	♂ 0 ♀ 11.1	11	0	100	0	7	50	100	0	2	28.6	100	50 60	7
11	66.7	100	16.7 0	9	33.3	100	0	3	44.4	100	20	9	0	100	0 66.7	9
12	50.0	100	0 50	4	0	100	0	3	38.5	100	0 37.5	13	0	100	0 100	1
13	66.7	100	25 0	6	37.5	100	0	8	33.3	100	0 50	12	16.6	100	100 100	6
14	25.0	100	0	4	33.3	100	0	6	71.4	100	0 50	7				
15	66.7	100	0	3	20.0	100	0	10	25.0	100	0 33.3	4				
16	0	100	0	1					28.6	100	0 20	7				
17	60.0	100	0	5					0	0	0	0				
18	50.0	100	0	4					0	100	0	3				

TABLE 9: Continued

	Trout Lake				Peter Lake				Lake 105				Brackish Waters			
Age	% Male	% Mature	% "WS"	N	% Male	% Mature	% "WS"	N	% Male	% Mature	% "WS"	N	% Male	% Mature	% "WS"	N
19	66.7	100	0 50	6					50.0	100	0 50	4				
20	37.5	100	0 50	8					50.0	100	0 50	4				
21	62.5	100	0	8					25.0	100	0 33.3	4				
22	50.0	100	50 0	4					0	100	0 33.3	3				
23	50.0	100	0 33.3	6					0	100	0 50	2				
24									0	100	0	1				
25									100.0	100	0	1				

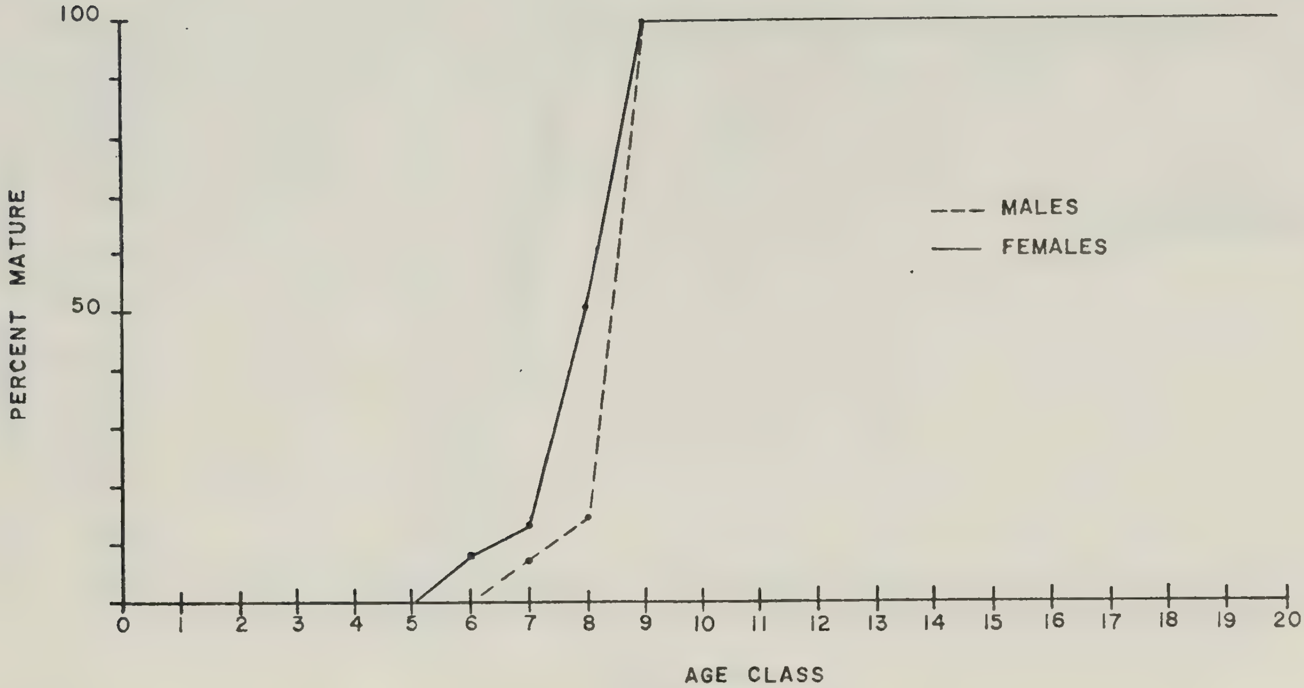


Figure 20. Age at maturity: Trout Lake normal cisco.

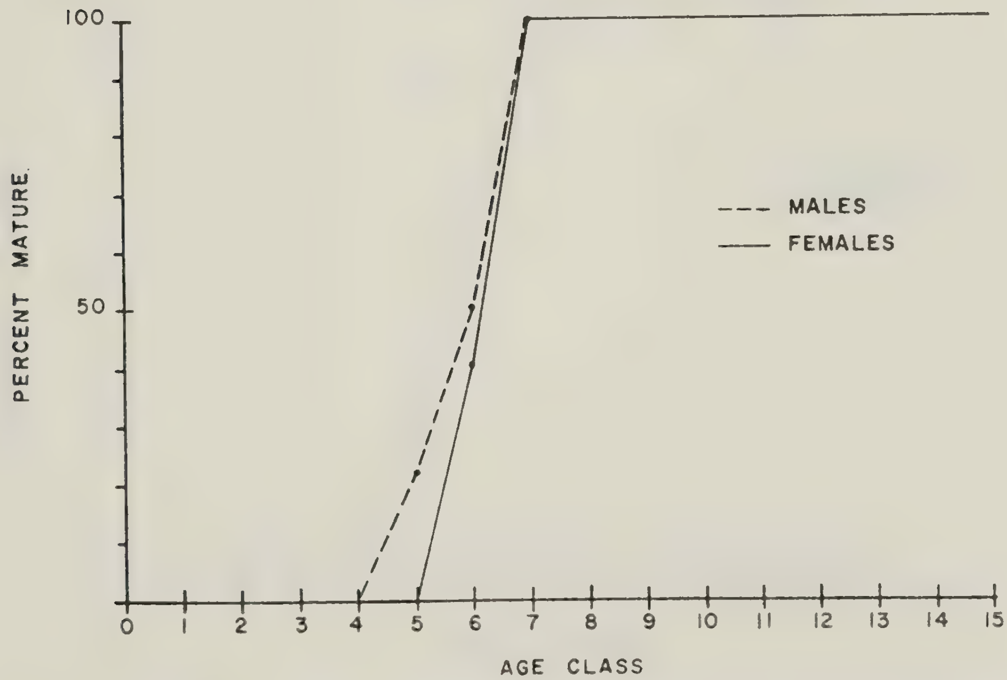


Figure 21. Age at maturity: Peter Lake normal cisco.

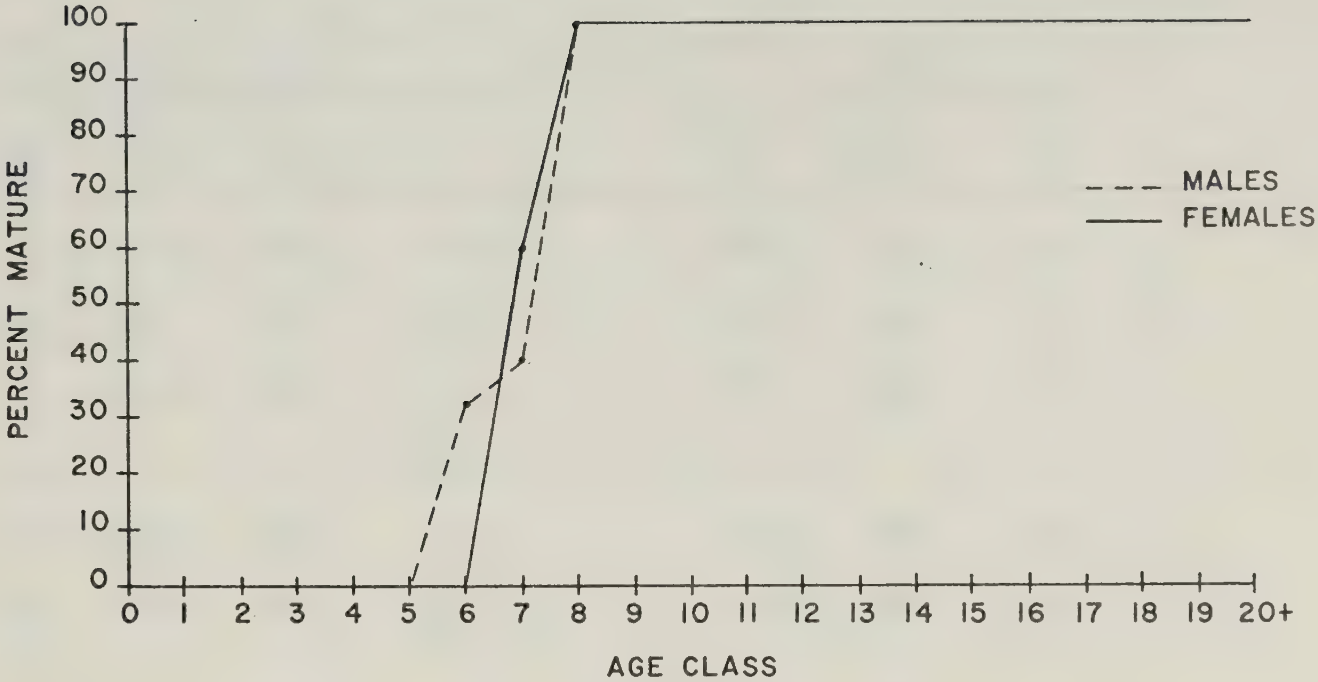


Figure 22. Age at maturity: Lake 105 cisco.

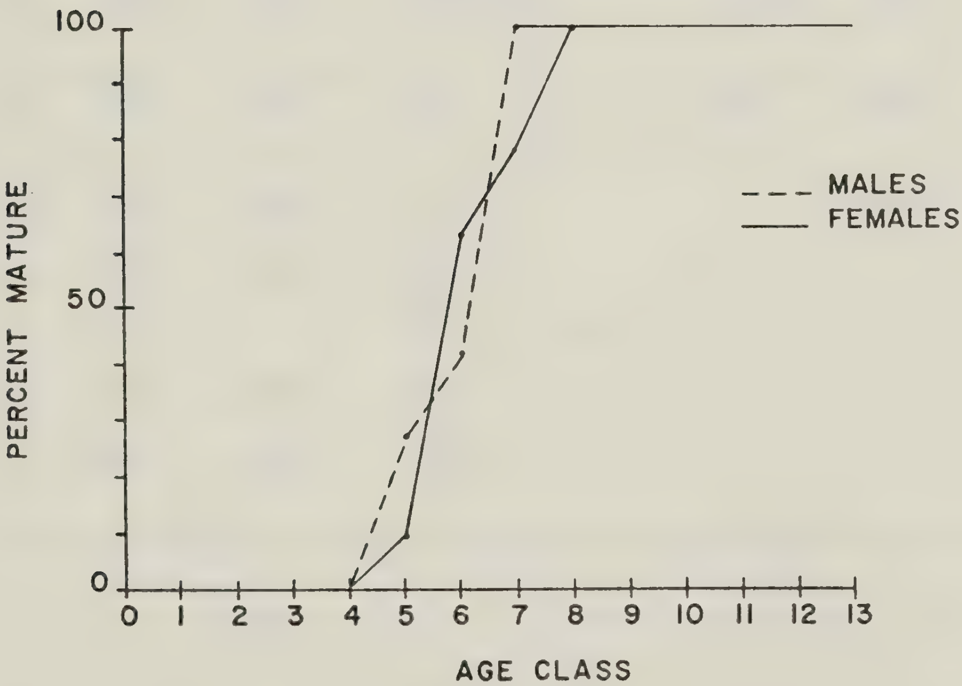


Figure 23. Age at maturity: Brackish water stations.

TABLE 10: Age, sex and maturity structure: Dwarf LSCS only.

	Trout Lake				Peter Lake			
Age	% Male	% Mature	% WS	N	% Male	% Mature	% WS	N
3	13.3	100	0	15	100	100	0	9
4	60	100	0	25	0	100	0	0
5	42.9	100	♂ 0 ♀ 12.5	14	100	100	0	6
6	57.2	100	0	14	66.6	100	0	3
7	55.6	100	80 0	9	62.5	100	0	8
8	0	100	0 25	4	62.5	100	0	8
9	83.3	100	20 0	6	50.0	100	0	2
10	100	100	100 0	1	100	100	0	2
11	0	100	0	3	0	100	0	2
12	100	100	100 0	1				
13	50	100	0	2				
14	100	100	0	1				

Age at Maturity

Tables 9 and 10 and Figure 20 - 23 indicate the age at which least cisco populations attain maturity.

The earliest maturing normal cisco populations were found to be in Peter Lake and brackish waters along the Beaufort Sea coast. Both populations are believed to be migratory and in both cases, males appear to mature earlier, on the average, than females. The earliest maturing individuals were aged at 5 years in both cases. Peter Lake least cisco samples were not 100% mature until age 7 and brackish water samples were not 100% mature until age 8. Migratory least cisco in the Colville River of Alaska are reported to begin maturing as early as age 4 (Alt and Kogl, 1973). Mackenzie River least cisco were found to be maturing by age 5, (Hatfield *et al*, 1972) which supports the theory that the brackish water population sampled during the present study is actually part of a much larger population which disperses from the Mackenzie River.

Of the 2 lake-resident populations of least cisco studied in the Yukon North Slope area, Trout Lake cisco were found to be the latest maturing. The youngest mature normal cisco in this population were age 6 and 100% maturity did not occur until age 9. The observation that females appear to precede males in attaining maturity is highly unusual in fish populations. Similarly, Lake 105 least cisco did not mature until age 6, but all individuals sampled had attained maturity by age 8. In this population males appear to begin maturing more quickly than do females, however, females approached 100% maturity

at a faster rate (in the 7th year).

It is difficult to determine whether the attainment of sexual maturity is a gradual process in dwarf least cisco since they could only be distinguished by their advanced gonad development. Immature dwarf least cisco could not be distinguished from similar sized immature normals since gonad development in both groups was minimal. In both the Trout Lake and Peter Lake dwarf populations, the youngest mature individuals were aged at 3 years. Figure 24 documents the complete lack of overlap in size of mature green, dwarf individuals and mature green, normal cisco in Trout Lake. Plate 15 illustrates that the relative size of male and female dwarf gonads are readily distinguishable from those of immature specimens, of the normal population of Trout Lake.

Sex Ratios

In the majority of least cisco populations studied, males were more abundant than females in total catches. Only in the Trout Lake normals and Peter Lake dwarf populations were males significantly more abundant (Chi square >10.0, $p<0.01$):

Population	N(total)	Percent Male	χ^2
Trout L.normal:	343	59.06	11.2396 ($p<0.005$)
Lake 105:	238	52.94	0.8234 ($p>0.05$)
Brackish water Stations:	168	54.17	1.1666 ($p>0.05$)
Peter L.normal:	101	44.55	1.1980 ($p>0.05$)
Trout L.dwarf:	95	47.37	2.6314 ($p>0.05$)
Peter L.dwarf:	40	75.00	10.000 ($p<0.01$)

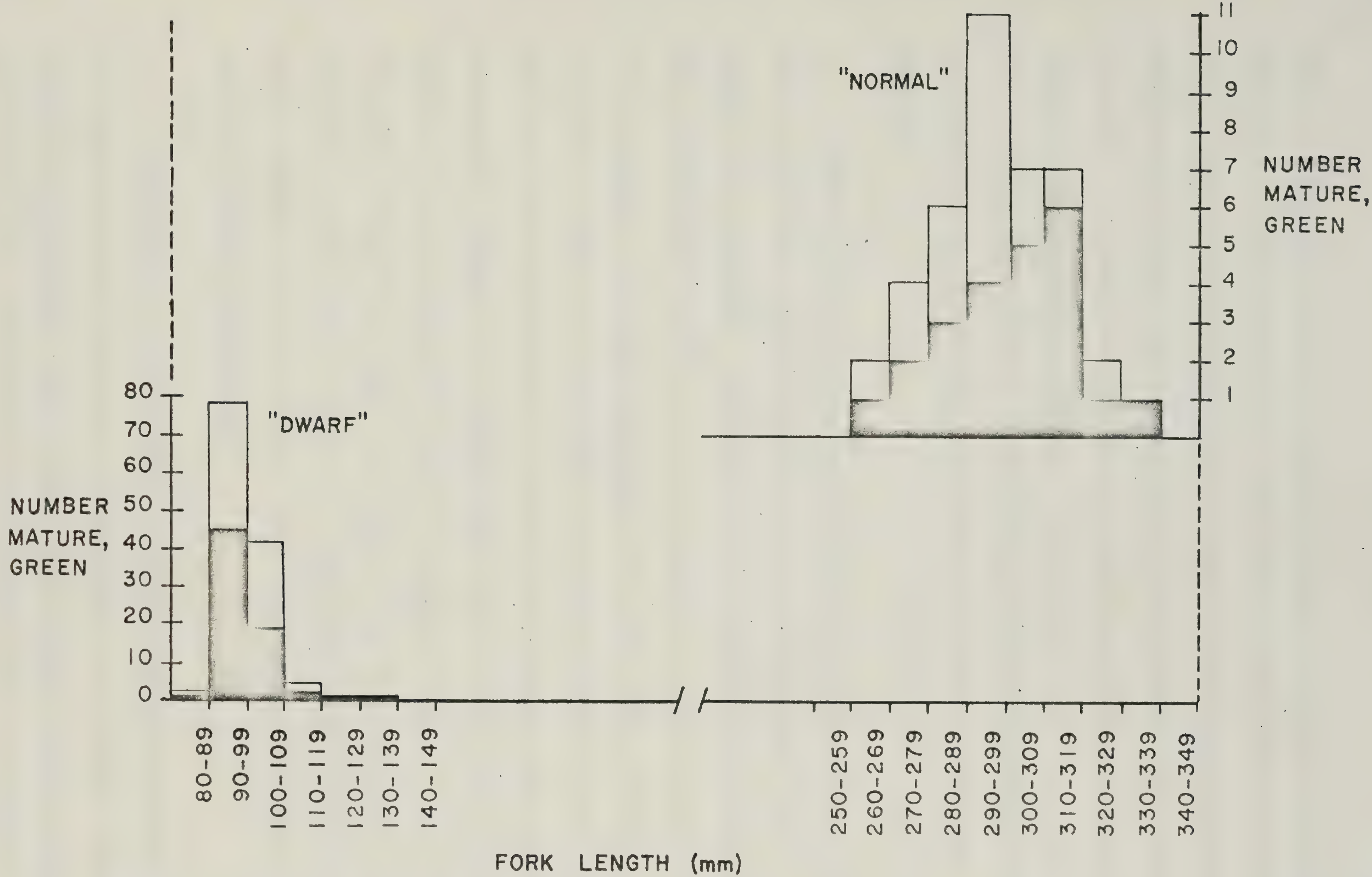


Figure 24. Trout Lake length-maturity relationships.

There is no ready explanation for the imbalance in the Trout Lake normal population. Since gillnets of a wide variety of mesh sizes were used at all times at varying depths and locations in the lakes and brackish water areas, it is not likely that any sex was selected for continually. Therefore, it is believed that these figures are a reliable indication of sex ratios in these populations. In most cases, the sex ratio favoured males more markedly in the younger age classes (Table 9, 10). As maximum age was approached, this favouring of males became less apparent.

Spawning run sex ratios could not be documented for most populations since peak activity occurred after freeze-up when field studies were terminated. In Peter Lake, NWT, however, both dwarf and normal populations were observed to be spawning by mid-September, 1973. It is suspected that these populations enter this lake during the spawning season, and may possibly overwinter there as well. In the normal spawning population it appears that females slightly outnumber males. Samples of spawning dwarf fish from Peter Lake, however, indicate a strong tendency for males to outnumber females. At the time of capture of dwarf specimens, most females were found to have released their eggs or were ripe in condition. Male gonads indicated that most had not spawned as yet but were also ripe since sperm could easily be expressed from the vas deferens.

Sex ratios in catches from the Mackenzie River near Arctic Red River favoured females (females = 57% Hatfield *et al*, 1972). Similarly, catches by Alt and Kogl (1973) in the Colville River favoured females approximately 2:1. The Mackenzie River samples were non-random in that

least cisco were taken only in September and represented a pre-spawning migration. The sex ratios reported by Alt and Kogl (1973) may not be representative of the entire population since only one-third of a single catch of 300 fish was analyzed.

Fecundity and Egg Size

Egg diameters were taken from each female which was judged to be mature at the time of sampling. The total diameter of 10 eggs dissected out and laid in a row was taken using calipers and the mean calculated. Diameters were taken for fresh, non water-hardened eggs only. Measuring of eggs less than 0.5 mm in diameter presented great difficulty, hence sample sizes of diameters for immature, and mature WS individuals are small.

Seasonal changes in egg diameter for populations of least cisco which could be sampled regularly are presented in Figures 25 and 26.

Growth in size of eggs which are to be released in the current year's spawning season appears to occur at a more or less constant rate during the summer months. Although the relative rates of development differ between populations, the egg diameter at spawning appears to be a relatively constant 1.5 mm. Populations which exhibit relatively later spawning seasons appear to enter the growth season with slightly larger egg diameters than early spawners (*eg* Trout Lake normal least cisco *vs* Trout Lake dwarfs - Figure 25, and Lake 105 cisco *vs* Brackish water migratory cisco -Figure 26). The data suggest that spawning egg diameter of dwarf least cisco may be slightly larger than

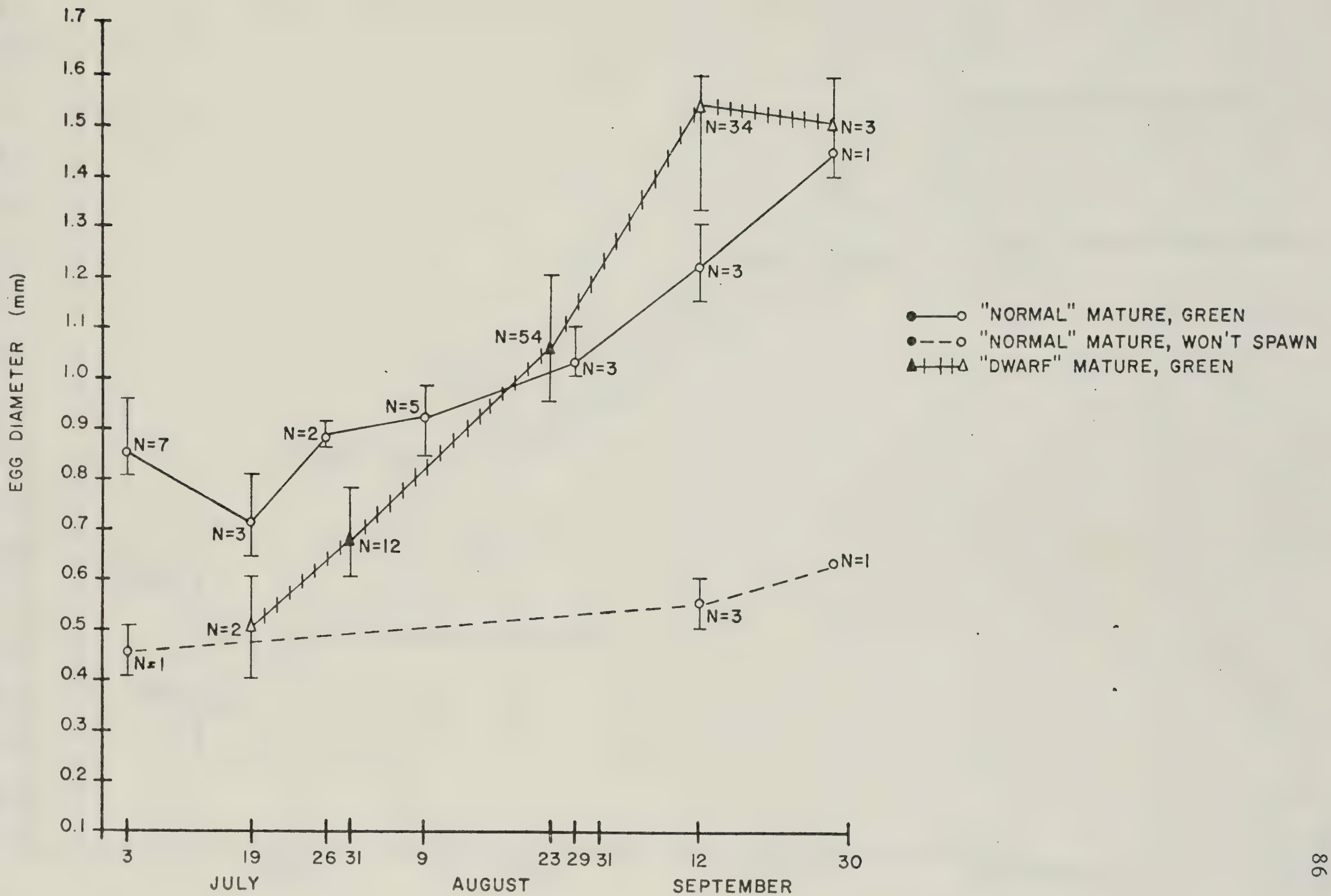


Figure 25. Seasonal change in egg diameter: Trout Lake.

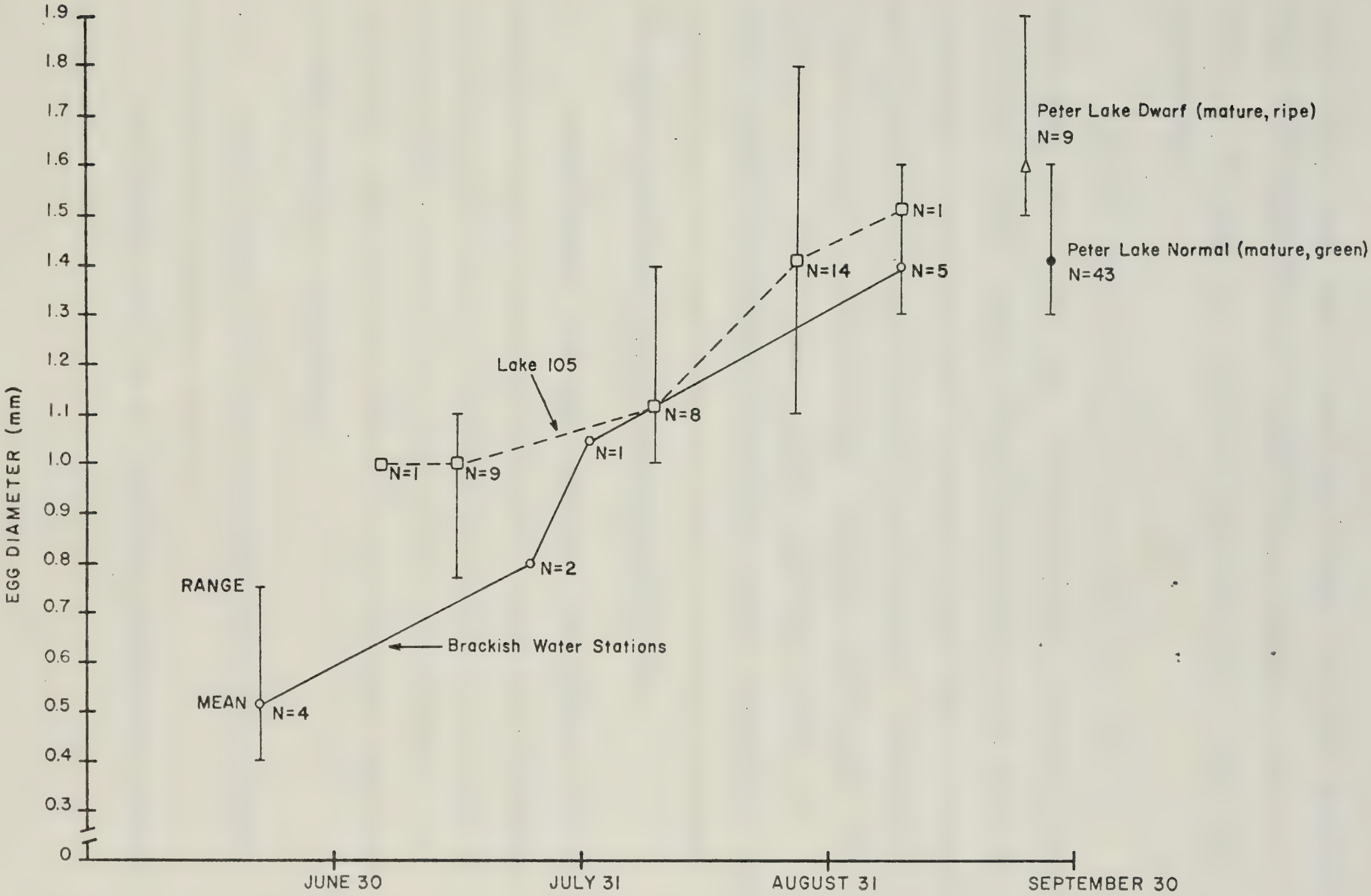


Figure 26. Seasonal change in egg diameter: Lake 105 and Brackish water stations.

that of normal least cisco in Peter Lake (Figure 26). Even though the normal cisco sample does not include ripe egg diameters, spawned-out females of this type were encountered in a catch from this lake only 10 days later.

Fecundity data were compared on the basis of relation to length (mm) and to weight (gm). In accordance with procedures suggested by Ricker (1968), fecundity-length and fecundity-weight data were transformed to logarithms prior to analysis. Since sample sizes were small in most cases, and since counts were necessarily conducted over a narrow range of lengths and weights, regression coefficients were typically low. Tables 11 and 12 present regression formulae for length-fecundity and weight-fecundity relationships respectively. Only 3 populations; Peter Lake normals and Lake 105 and Trout Lake dwarf fish showed significant ($p < .05$) regression coefficients.

Length-fecundity and weight-fecundity relationships were compared by analysis of covariance. (Table 13). Significant differences in slope and elevation (y - intercept) were observed in all cases of intra-population comparison of length-fecundity relationships. No significant differences were observed in inter-population comparison of weight-fecundity relationships.

Length-fecundity and weight-fecundity regressions are graphically presented in Figures 27 and 28.

Raw fecundity data for the populations examined are presented in Appendix 6.

TABLE 11: Length-fecundity relationship:

Peter Lake "N":

$\text{Log } F = 2.8018 (\text{Log } L) - 2.9695$, $r=0.4721$, $N=23$

Lake 105:

$\text{Log } F = 3.3059 (\text{Log } L) - 4.1846$, $r=0.7295$, $N=22$

Trout L. "D":

$\text{Log } F = 1.4802 (\text{Log } L) - 0.3379$, $r=0.4164$, $N=34$

TABLE 12: Weight-fecundity relationships:

Peter Lake "N":

$\text{Log } F = 1.0774 (\text{Log } W) + 1.3757$, $r=0.5305$, $N=28$

Lake 105:

$\text{Log } F = 1.0652 (\text{Log } W) + 1.3474$, $r=0.7391$, $N=22$

Trout L. "D":

$\text{Log } F = 0.6247 (\text{Log } W) + 2.0281$, $r=0.4015$, $N-34$

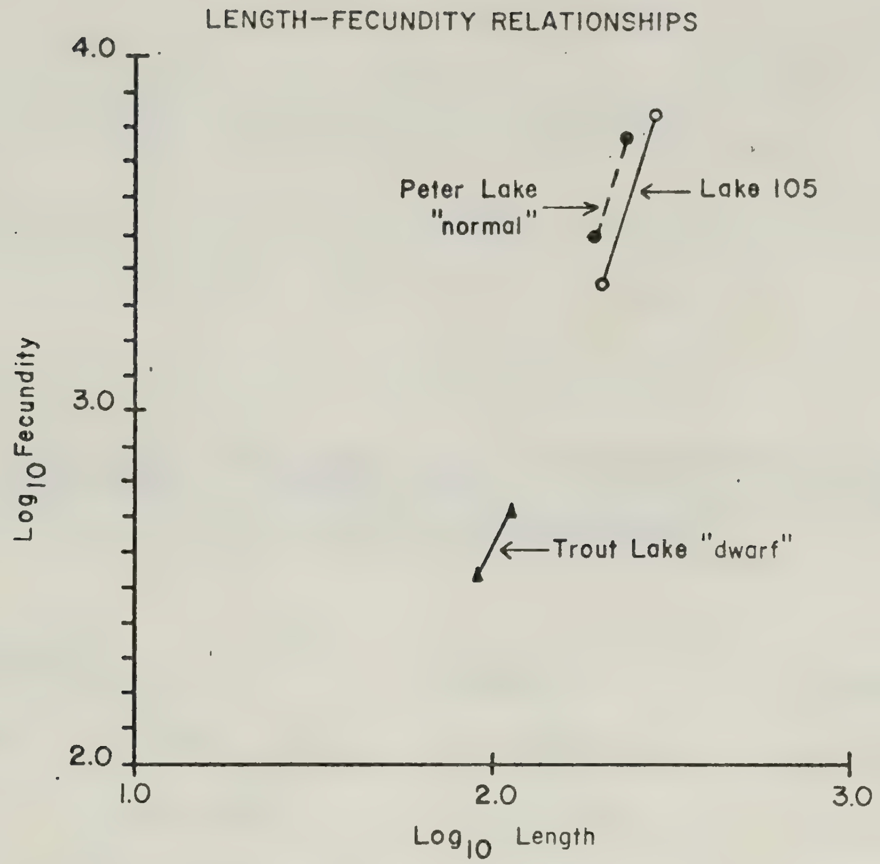


Figure 27. Length-fecundity relationships.

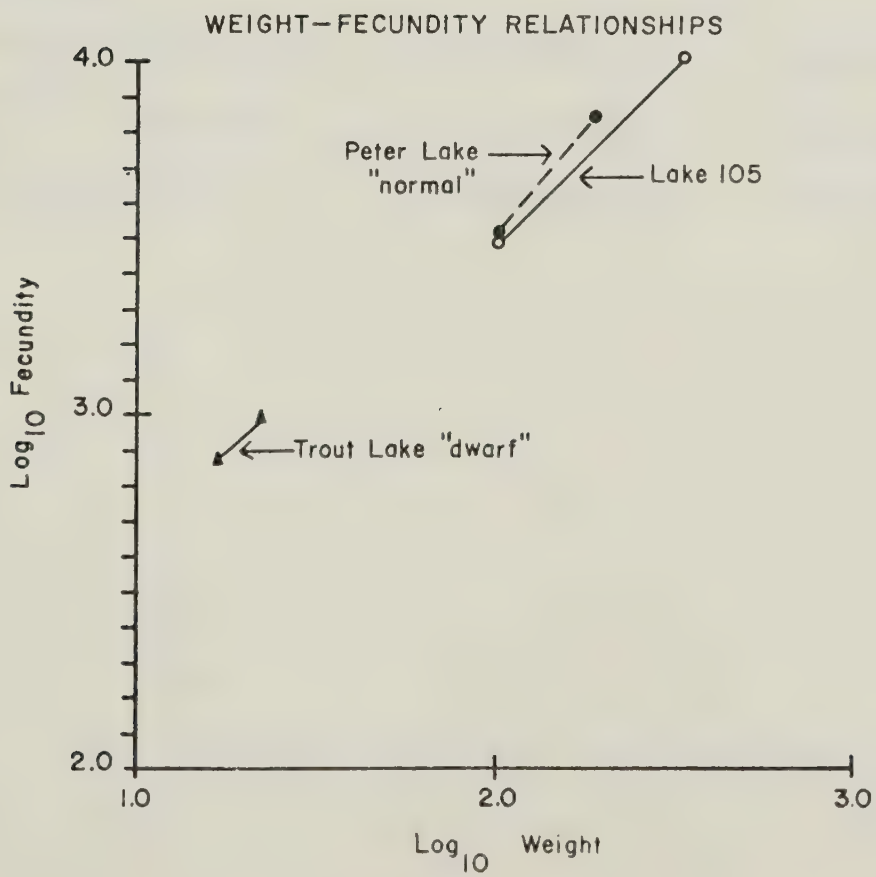


Figure 28. Weight-fecundity relationships.

TABLE 13: Analysis of covariance for length-fecundity and weight-fecundity regressions. *=significant at 0.05% level, **=significant at 0.01% level, n.s.=not significantly different.

Length-fecundity	Slope	Elevation
Trout Lake "D" x Peter L."N"	F=4.9484(*)	F=44.9646(**)
Trout Lake "D" x Lake 105	F=4.3111(*)	F=5.6563 (*)
Lake 105 x Peter L. "N"	F=18.7980(**)	F=54.3949(**)
Weight-fecundity		
Trout Lake "D" x Peter L."N"	F=1.0984(n.s.)	F=0.3535(n.s.)
Trout Lake "D" x Lake 105	F=1.0142(n.s.)	F=0.0783(n.s.)
Lake 105 x Peter L."N"	F=0.0068(n.s.)	F=3.8920(n.s.)

Spawning Season and Distribution in Study Areas

There was no sampling beyond the end of September in either year of this study so that observations on spawning times of the least cisco populations are therefore incomplete.

The earliest spawning population examined was the dwarf *C. sardinella* of Peter Lake. The first ripe and spawned-out individuals were encountered in September 10, 1973 gillnet catches. Unfortunately, this was the date on which the first females of this population were captured and only a single female was observed to contain its complete complement of eggs, therefore only a single fecundity count could be obtained. On this occasion, spawning fish were encountered only at Station 3 (Figure 9) on the west shore of Peter Lake. Gillnet gangs were set in the lake at all 4 stations from September 7 to September 10, 1973, inclusive; however, the only catch of dwarf least cisco during this period occurred on September 10th. Only 3 specimens of dwarf cisco were taken in a heavy catch of normal least cisco on September 3, 1973, and all were green males. Gillnets of similar mesh sizes (3/4" and 1") set in the lake on September 20, 1973 and checked at approximately 3-hour intervals, captured only 2 spawned-out dwarf cisco during the 24 hours of fishing. These data suggest a very narrow spawning season of less than 10 days for this group.

Normally-growing least cisco captured in Peter Lake were somewhat later in their time of spawning. Ripe and spawned-out males and females were not captured until the last date of sampling,

September 20-21, 1973. This group may have a somewhat longer spawning season than the dwarf population since a single ripe specimen of the normal type was captured in this lake in the previous field season (October 5, 1972).

It appears then that gene flow between these two migratory forms captured in Peter Lake may be somewhat restricted due to temporal isolation of spawning time. However, since spawning times occur so closely, the opportunity for hybridization may still be present, provided other isolating mechanisms do not exist.

A similar situation may exist between the normal and dwarf populations of *C. sardinella* inhabiting Trout Lake. The 1972 field investigations terminated in mid-September, immediately prior to lake freeze-over, and at this time, no indication of commencement of spawning was observed. In 1973, the last field data collection made was on September 25-26 and on this date, the first ripe specimens of the dwarf type were captured. Only 4 specimens were collected, 3 ripe females and a single green male. Freeze-over of the lake occurred 2 days after this date and at this time no specimens of the normal type were observed to be in a ripe condition, although the egg diameter of green females closely approached the spawning egg diameter of 1.5 mm (Figure 25). It appears then, that spawning of normal least cisco in Trout Lake occurs after freeze-up, under lake ice. These findings concur with observations of least cisco in Ikroavik Lake- Point Barrow, Alaska (Cohen, 1954).

Anadromous least cisco associated with the North Slope

coastal brackish water areas had a seasonal distribution in the study area reflecting the spawning habits of this life history type. Figure 29 illustrates the relative abundance of least cisco in brackish water areas along the Yukon-Beaufort Sea coast. Although sites were not sampled concurrently during the 2 years of field studies, the catch per unit effort (net hours), illustrates that the nearer one comes to the Mackenzie Delta, the more abundant least cisco become in gillnet catches. This strongly suggests that the brackish-water population sampled during these studies are dispersed in a westward direction from the Mackenzie Delta area.

Stokes Point Lagoon (Figure 1) was sampled at approximately 3-week intervals during the 1973 field season and the data illustrate a distributional trend also observed at other brackish waters sites sampled less regularly. Figure 30 indicates an initial increase in total catch per unit effort from mid-July to early August 1973, and thereafter, a decline to zero in mid-September. From mid-July until late August, a continual decline in numbers of mature green individuals occurred in gillnet catches in this lagoon. It is believed that this distributional pattern occurred due to spring and early summer dispersal from the Mackenzie River of approximately equal numbers of green and WS individuals, probably in response to greater food abundance along coastal brackish water areas. As the summer progressed, it is thought that individuals which would spawn in the fall began returning to the Mackenzie River and its delta tributaries at a faster rate than individuals which were immature or in a resting stage (WS). The progressive decrease in total catch per unit effort

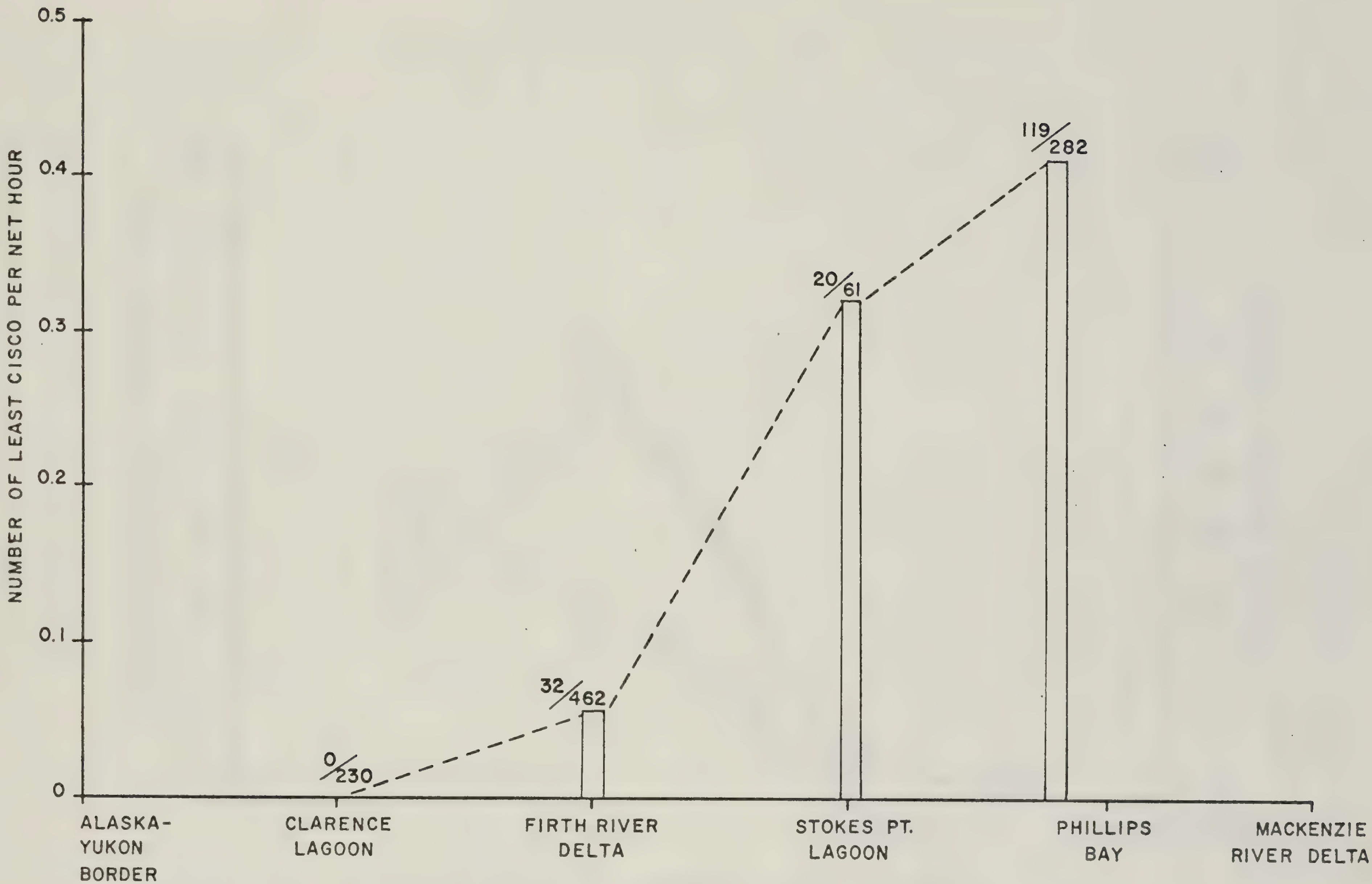


Figure 29. Distribution and abundance of Least cisco along the Beaufort Sea Coast.

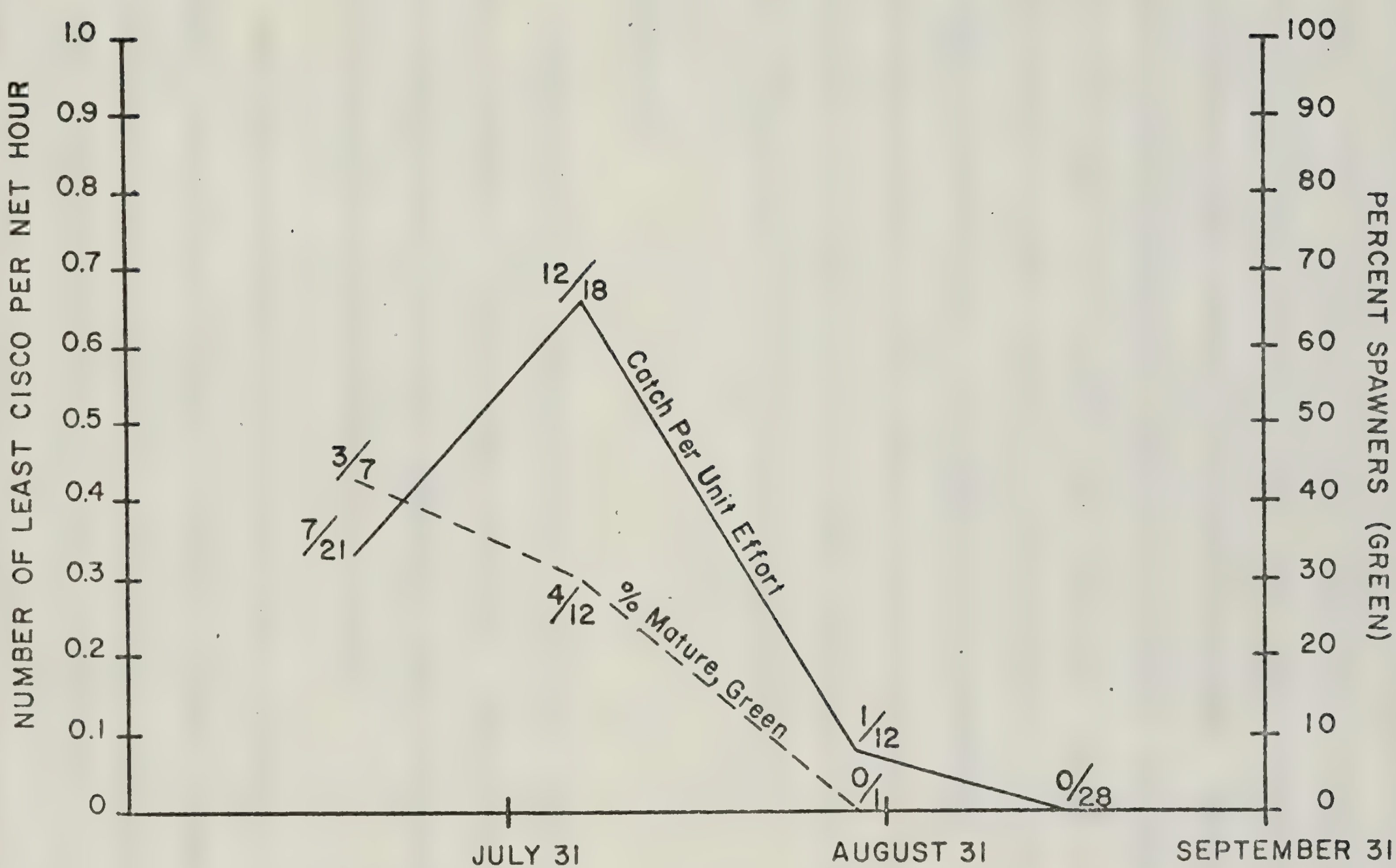


Figure 30. Seasonal change in abundance and condition of Least Cisco in Stokes Point Lagoon, 1973.

illustrates that non-spawning least cisco do not overwinter in coastal waters but probably return to the Mackenzie River later than spawning individuals. Further evidence for this hypothesis is presented by Hatfield *et al*, (1972), who report that least cisco did not appear in Mackenzie Delta gillnet catches until early September. Mature, green individuals became increasingly abundant in gillnets and dominated catches in all areas until studies were terminated. In the same area in 1972, Stein *et al* (1973) report a gradual increase in abundance of least cisco in gillnets from late August until mid-October. Ripe *C. sardinella* were taken in Peel Channel and Husky Channel in the Mackenzie River Delta and also in the Peel River near Arctic Red River settlement during late September and early October 1972.

Least Cisco Fry

Growth data for *C. sardinella* fry in the Yukon study area are presented in Figure 17. As mentioned previously, considerable difficulty was encountered in obtaining samples of young-of-the-year therefore the data are not as continuous as was hoped.

When collections were made in Trout Lake or Lake 105, a record of locality, bottom type, presence or absence of aquatic vegetation, water temperature, weather and water conditions and seining effort was kept. Table 14 presents these data. There are several obvious trends:

1) least cisco fry were commonly captured near shore on calm days when water turbulence was minimal.

2) fry were rarely captured in the same areas as juvenile least

TABLE 14: Least cisco fry collection data: Trout Lake

Date	Weather	Bottom type	Aquatic Veg.	Water Temp. °C	Seining effort	Catch**
Aug.19/72	Overcast calm	1)clay-shale fragments	none	12	8 x 100' (hauls) (20'-2man seine)	1 LSCS fry 1 Gray.juv.
		2)shale fragments, clay ooze	sedges present	--	6 x 100'	2 LSCS juv. 1 LSCS fry 1 Gray.juv.
Aug.23/72	sunny-calm-windy(15 mph) wave action	1)clay-shale fragments	none	15	3 loops (60' seine)	57 LSCS fry
		2)clay-ooze	none	14.5	3 loops	1 LSCS adult 2 Gray.juv.
		3)clay-ooze	present	--	3 loops	13 LSCS juv.
June 10/73	clear-anchor ice still present	1)clay-shale fragments	present	4	4 x 100' (hauls) (20'seine)	1 St.Bk.
Jul. 3/73	clear-calm	1)clay-shale	none	7	2 x 100' (hauls) (20'seine)	nil
Jul.30/73	overcast calm	1)clay-shale	none	15.5	2 x 100' (20'seine)	44 LSCS fry
		2)shale and organic debris	none		1 x 100' (hauls)	1 LSCS fry 10 St.Bk.

TABLE 14: Continued

Date	Weather	Bottom type	Aquatic Veg.	Water Temp. °C	Seining effort	Catch**
		3)clay,ooze and rock fragment	present		2 x 100' (hauls)	21 LSCS juv. 50 Gray.juv. 2 St.Bk.
July.31/73	clear-calm	1)shale fragement and organic debris	present	15.5	1 x 200' (hauls)	3 St.bk.
		2)shale fragment	none		1 x 100'	~300 LSCS fry
Aug.19/73	overcast windy(n15mph)	1)clay-shale fragment	none	13	5 x 100'	13 LSCS fry
Aug.28/73	overcast calm	1)clay-shale fragment	none	11	10 x 100' (hauls)	1 LSCS fry
Sept.16/73	overcast windy(n20mph)	1)clay-shale	none	8	4 x 100'	3 LSCS juv.
		2)clay-ooze	present		4 x 100'	6 St. Bk.
Aug. 8/73	clear-calm	1)organic ooze cobbles and rubble(3'water depth)	sedges abundant	12.5	1 x 30' (20'seine)	108 LSCS juv. 3 LSCS fry 2 St. Bk.
		2)fine gravel (3'water depth)	none		3 x 100'	1 LSCS fry 1 LKTR fry
		3)gravel(6"water depth)	none		2 x 50'	13 LSCS fry 1 LKTR fry

TABLE 14: Continued

Date	Weather	Bottom type	Aquatic Veg.	Water Temp. °C	Seining effort	Catch**
		4) cobbles	present		2 x 159"	1 LSCS juv. 1 LSCS fry 1 St.Bk.
Aug. 28/73	overcast windy	same areas covered	same effort			1 LSCS fry 1 LKTR fry
Sept.16/73	overcast calm	1) ooze,cobble	present	8.0	5 x 100' (hauls)	6 LSCS fry 2 Gray.fry 6 St.Bk.
		2) gravel,cobbles	absent		5 x 100' (hauls)	15 LSCS fry Large school LSCS fry seen but not captured.

** Species codes: LSCS = Least cisco

Gray.= Arctic grayling

St.Bk= 9-spine stickleback

LKTR = Lake Trout.

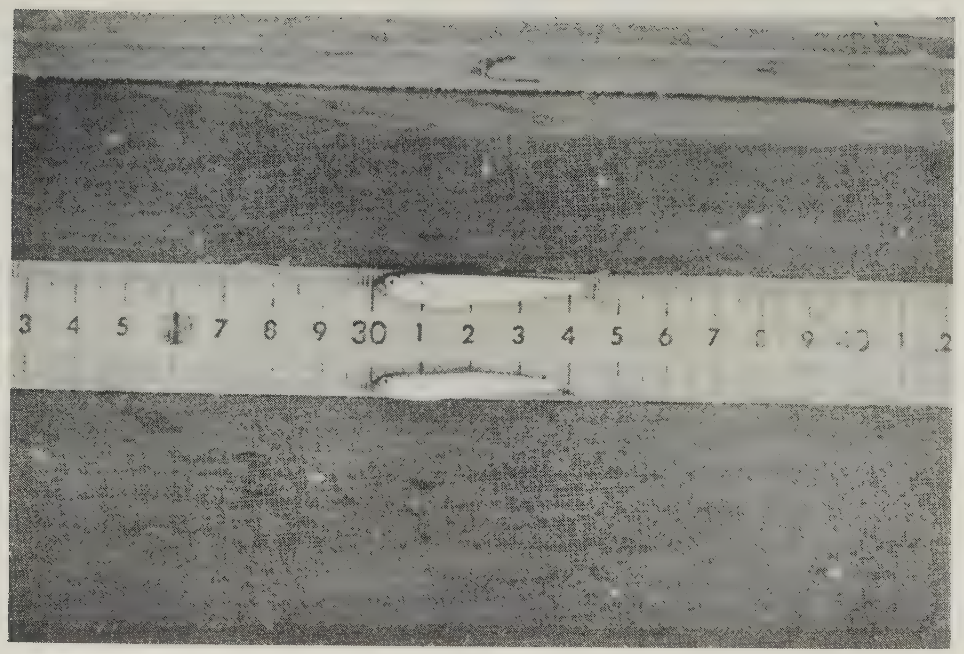


Plate 16. Least cisco fry from Trout Lake, captured in late August, 1972.

Plate 17. Typical shale fragment beach of Trout Lake where fry were commonly captured.

cisco (fork length 100 to 150 mm).

3) least cisco fry appear to prefer areas in which rooted aquatic vegetation is lacking, whereas juveniles appear to prefer vegetated areas.

4) fry do not appear to prefer one bottom type over another, although large catches occurred most commonly in areas of shale fragments and gravels. (Plates 16, 17).

Feeding habits of least cisco dry were not examined in detail, however, in the 20 stomachs examined, a wide variety of food items were found. Trout Lake specimens contained bottom fauna (small Chironomidae larvae - 4/10), zooplankton (Cladocera: *Alona* sp. *Bosmina* sp. 6/10) and surface insects (Hymenoptera, Diptera adults: 4/10). The Lake 105 fry examined were feeding exclusively on zooplankton.

Scale development was complete on specimens examined which were taken from Lake 105 in mid-September, 1973. This observation concurs with those made for least cisco fry captured on Point Barrow, Alaska (Cohen, 1954).

Food Habits

The results of stomach content analysis conducted during the 2-year study period are presented in Tables 15, 16 and 17 and Figure 31. For reasons stated previously (Page 32), results are represented in terms of frequency of occurrence (%) of food items.

Feeding data were arbitrarily broken up into 3 periods for

TABLE 15: Continued

Food Item	Trout Lake "Normal" Occurrence (%) Period[i]			Lake 105 Occurrence (%) Period[i]			Brackish Water Stations Occurrence (%) Period[i]		
	1	2	3	1	2	3	1	2	3
Hemiptera	0 (0)	0 (0)	8 (50)	(0) (0)	(0) (0)	(0) (0)	0 (0)	0 (0)	0 (0)
Gastropoda	23 (42.6)	11 (52.4)	5 (31.3)	2 (16.7)	9 (21.4)	1 (2.8)	0 (0)	0 (0)	0 (0)
Pelecypoda	1 (1.9)	0 (0)	0 (0)	11 (91.7)	20 (47.6)	13 (36.1)	0 (0)	0 (0)	0 (0)
Fish remains	2 (3.7)	5 (23.8)	1 (6.3)	0 (0)	1 (2.4)	0 (0)	0 (0)	0 (0)	0 (0)
Organic debris and vegetation	2 (3.7)	1 (4.8)	0 (0)	1 (8.3)	0 (0)	1 (2.8)	0 (0)	3 (6.1)	0 (0)
Empty	1 (1.9)	0 (0)	2 (12.5)	0 (0)	4 (9.5)	1 (2.8)	0 (0)	6 (12.2)	1 (50.0)
Number of Stomachs examined	54	21	16	12	42	36	9	49	2

TABLE 15: Stomach content analysis: Mature, normal least cisco.

Food Item	Trout Lake "Normal" Occurrence (%) Period i			Lake 105 Occurrence (%) Period i			Brackish Water Stations Occurrence (%) Period i		
	1	2	3	1	2	3	1	2	3
Amphipoda [f]	19 (35.2)	3 (14.3)	0 (0)	0 (0)	9 (21.4)	19 (52.8)	7 (77.8)	15 (30.6)	0 (0)
Other crustacea[a,e] (Macroscopic)	0 (0)	0 (0)	0 (0)	0 (0)	3 (7.1)	2 (5.6)	1 (11.1)	19 (38.8)	2 (100)
Zooplankton (Microscopic Crustacea)	1 (1.9)	0 (0)	0 (0)	4 (33.3)	0 (0)	13 (36.1)	3 (33.3)	9 (18.4)	0 (0)
Surface insects (Adults)	3 (5.6)	3 (14.3)	0 (0)	0 (0)	1 (2.4)	3 (8.3)	0 (0)	8 (16.3)	0 (0)
Diptera:Larvae, Pupae	32 (59.3)	3 (14.3)	2 (12.5)	1 (8.3)	7 (16.7)	2 (5.6)	0 (0)	19 (38.8)	0 (0)
Miscellaneous[b,c,d] Insects	0 (0)	0 (0)	1 (6.3)	1 (8.3)	0 (0)	1 (2.8)	0 (0)	6 (12.2)	0 (0)
Unidentifiable Insects	0 (0)	0 (0)	1 (6.3)	0 (0)	0 (0)	0 (0)	0 (0)	3 (6.1)	0 (0)

TABLE 16: Stomach content analysis: Immature, normal and mature dwarf least cisco.

Food item	Trout Lake Immature:"Normal" Occurrence (%) Period[i]			Trout Lake Mature:"Dwarf" Occurrence (%) Period[i]			Lake 105 Immature Occurrence (%) Period[i]			Brackish Water Immature Occurrence (%) Period[i]		
	1	2	3	1	2	3	1	2	3	1	2	3
Amphipoda [f]	4 (5.3)	11 (10.1)	0 (0)	0 (0)	1 (3.1)	0 (0)	0 (0)	50 (41.7)	1 (7.1)	1 (33.3)	14 (16.1)	2 (40.0)
Other Crustacea [a,e] (Macroscopic)	0 (0)	1 (0.9)	0 (0)	0 (0)	1 (3.1)	0 (0)	0 (0)	3 (2.5)	0 (0)	2 (66.7)	8 (9.2)	5 (100)
Zooplankton (Microscopic Crust)	1 (1.3)	9 (8.3)	0 (0)	0 (0)	1 (3.1)	4 (14.3)	11 (91.7)	39 (32.5)	12 (85.7)	2 (66.7)	10 (11.5)	0 (0)
Surface insects (Adults)	25 (33.3)	39 (35.8)	55 (56.1)	2 (18.2)	7 (21.9)	19 (67.9)	0 (0)	1 (0.83)	0 (0)	0 (0)	28 (32.7)	0 (0)
Deptera:Larvae, Pupae	48 (64)	53 (48.6)	0 (0)	9 (81.8)	23 (71.9)	0 (0)	1 (8.3)	2 (1.7)	0 (0)	0 (0)	38 (43.7)	0 (0)
Miscellaneous [b,c,d] Insects	6 (8.0)	22 (20.2)	1 (1.02)	0 (0)	4 (12.5)	1 (3.6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Unidentifiable Insects	3 (4.0)	4 (3.7)	2 (2.04)	3 (27.3)	0 (0)	1 (3.6)	0 (0)	0 (0)	0 (0)	0 (0)	8 (9.2)	0 (0)

TABLE 16: Continued

Food item	Trout Lake Immature: "Normal" Occurrence (%) Period			Trout Lake Mature: "Dwarf" Occurrence (%) Period			Lake 105 Immature Occurrence (%) Period			Brackish Water Immature Occurrence (%) Period		
	1	2	3	1	2	3	1	2	3	1	2	3
Hemiptera	0 (0)	0 (0)	25 (25.5)	0 (0)	0 (0)	4 (14.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Gastropoda	4 (5.3)	8 (7.3)	10 (10.2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Pelecypoda	0 (0)	0 (0)	1 (1.02)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.83)	1 (7.1)	0 (0)	0 (0)	0 (0)
Fish remains	0 (0)	1 (0.9)	3 (3.1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Organic Debris and vegetation	1 (1.3)	4 (3.7)	3 (3.06)	0 (0)	1 (3.1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	6 (6.9)	0 (0)
Empty	1 (1.3)	11 (10.1)	10 (10.2)	0 (0)	6 (18.8)	7 (25)	0 (0)	36 (30)	0 (0)	0 (0)	10 (11.5)	0 (0)
Number of Stomachs examined	75	109	98	11	32	28	12	120	14	3	87	5

TABLE 17: Stomach content analysis: Peter Lake, 1973

Food Item	Peter Lake:"Normal" Mature Occurrence (%) Period 3	Peter Lake:"Normal" Immature Occurrence (%) Period 3	"Dwarf" Mature Occurrence (%) Period 3
Amphipoda	0 (0)	0 (0)	0 (0)
Other Crustacea (Macroscopic)	0 (0)	0 (0)	0 (0)
Zooplankton (Microscopic Crust.)	47 (64.4)	28 (0.3)	12 (30.8)
Surface Insects (Adults)	2 (2.7)	1 (3.2)	0 (0)
Diptera:Larvae, Pupae	6 (8.2)	0 (0)	0 (0)
Miscellaneous Insects	1 (1.4)	0 (0)	0 (0)
Unidentifiable Insects	0 (0)	0 (0)	0 (0)
Hemiptera	13 (17.8)	3 (9.7)	0 (0)
Gastropoda	0 (0)	0 (0)	0 (0)
Pelecypoda	1 (1.4)	0 (0)	0 (0)
Fish Remains	0 (0)	0 (0)	0 (0)
Organic Debris and Vegetation	0 (0)	0 (0)	1 (2.6)

TABLE 17: Continued

Food Item	Peter Lake:"Normal" Mature Occurrence (%) Period[i]	Peter Lake:"Normal" Immature Occurrence (%) Period[i]	"Dwarf" Mature Occurrence (%) Period[i]
	3	3	3
Empty	16 (21.9)	10 (32.3)	28 (71.8)
Number of stomachs examined	73	31	39

Footnotes for Tables 15, 16, 17.

[i] Period 1= June 15 to July 15.

Period 2= July 16 to Aug.15.

Period 3= Aug. 16 to Sept.30.

a For Lake 105 includes: *Mysis relicta*

b For Lake 105 includes: Hydracarina sp.,Trichoptera Larvae

c For Trout Lake includes: exclusively Hydracarina sp.

d For Brackish Water Stations included: Plecoptera (*Leuctra (moselia) infuscata)*, Ephemeroptera and Trichoptera nymphs.

e For Brackish Water Stations includes: (in order of abundance);

Coperoda: *Calanus hyperboreus*

Mysidacea: *Mysis oculata (?)*

Cumacea: *Diastylis sulcata (?)*

Isopoda: *Saduria (Mesidotea) entomon*

f For Brackish Water Stations:

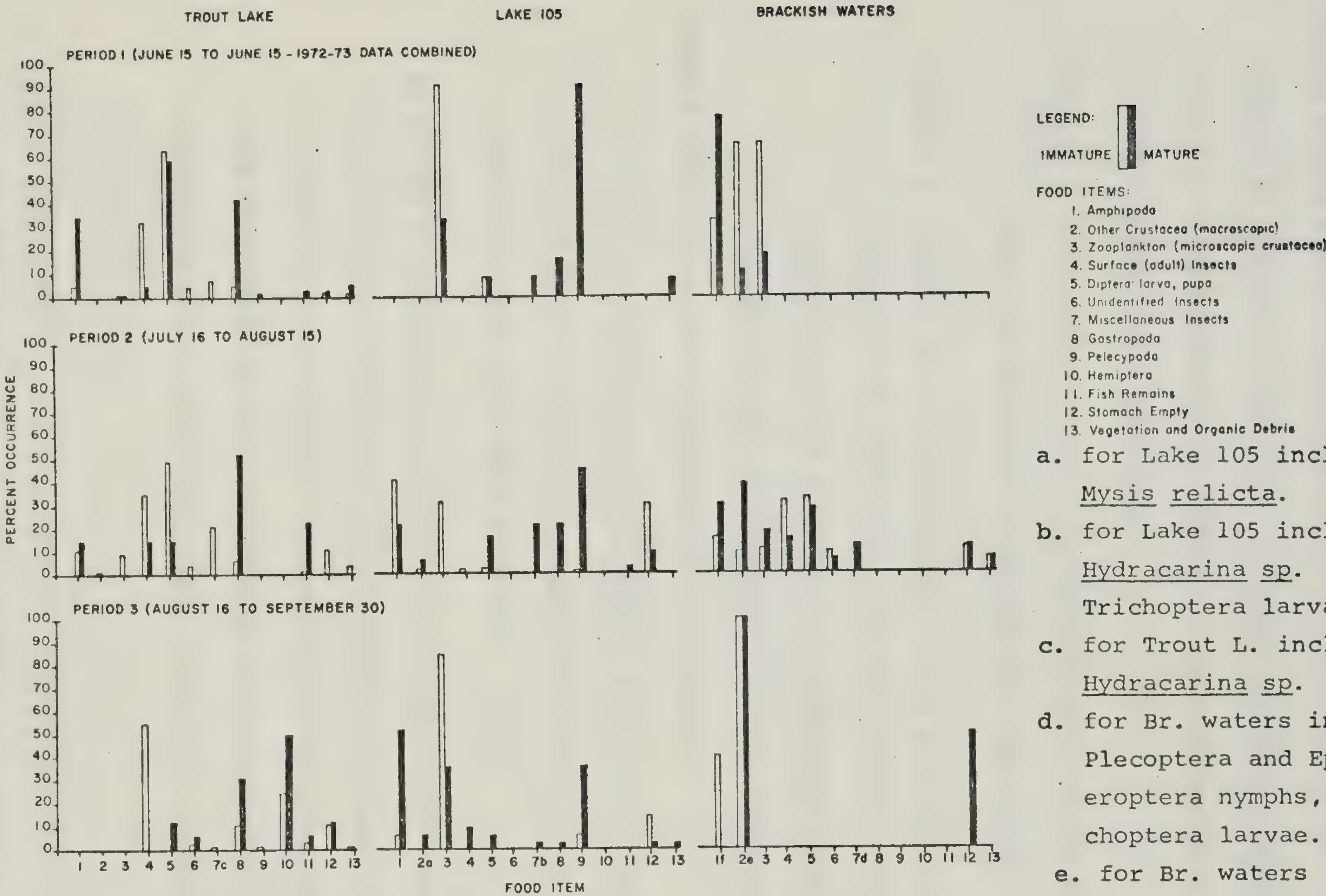
Amphipoda:

Gammarus setosus

Pseudalibrotus litoralis

Pontogeniea sp.

Figure 31. Stomach content analysis.



a. for Lake 105 includes: Mysis relicta.

b. for Lake 105 includes: Hydracarina sp. Trichoptera larvae.

c. for Trout L. includes: Hydracarina sp.

d. for Br. waters includes: Plecoptera and Ephemeroptera nymphs, Trichoptera larvae.

e. for Br. waters includes: (in order of abundance) Copepoda; Calanus hyperboreus, Mysidacea; Mysis oculata(?), Cumacea; Diastylus sulcata(?), Isopoda; Saduria(mesidotea)entomon

f. for Br. water stations includes: Amphipoda; Gammarus setosus, Pseudalibrotus litoralis, Pontogenia sp.

purposes of analysis, to determine if any change in feeding habits occurs during the ice-free season.

Period 1 (June 15 to July 15) included the time in which growth was beginning but little or none was yet recorded on scales and otoliths.

Period 2 (July 16 to August 15) included the time in which food was most abundant and growth was most rapid.

Period 3 (August 16 to September 30 - last sampling date was September 26, 1973) included the period in which air temperatures and water temperatures were rapidly declining, as was the abundance of food organisms.

Feeding observations may be summarized as follows:

1) All least cisco populations examined during the study periods appear to be generalists in their food habits since a wide variety of food items were recorded.

2) Of the 3 populations examined in the Yukon North Slope study area, brackish-water least cisco appear to be most selective in their feeding habits. Crustacea were the food items encountered most often at all times during the study but this is probably a reflection of the great abundance of these organisms in brackish waters.

3) The opportunistic feeding nature of the least cisco is reflected by the observation that bottom, pelagic and surface allochthonous food items were encountered in stomachs from all 3 populations intensively studied.

4) In the Trout Lake and brackish-water populations, selection of food by immature and mature individuals did not markedly differ in any of the three periods. (Tables 15, 16 and Figure 31).

5) In Lake 105, immature least cisco fed more commonly on crustacean fauna (specifically zooplankton or misroscopic crustacea) than did adults. Lake 105 adult cisco fed most commonly on bottom dwelling Pelecypoda (Sphaeriidae) during the first 2 periods (Tables 15, 16 and Figure 31).

6) In the early spring and summer and fall periods (periods 1 and 3 respectively), least cisco had less diversity in the food items in their stomach contents (Figure 31).

7) The least cisco captured in Peter Lake, NWT, appear to utilize zooplankton to a considerable degree. (Table 17).

8) The relatively common occurrence of empty stomachs in samples of dwarf least cisco from Peter Lake suggests that feeding does not occur during the brief spawning season. (Table 17).

9) Trout Lake dwarf least cisco and immature normal cisco were commonly captured in the same areas, and this is reflected in the lack of difference in the diets of these 2 groups during the 3 study periods. (Table 16).

In spite of their abundance, least cisco in Lake 105, appear to suffer very low levels of predation by the lake trout in the summer months. Only 5 out of 17 lake trout stomachs examined contained fish remains, and only 1 contained a least cisco; the remainder were 9-spined sticklebacks.

The results of this study indicate that the least cisco in the study area are not strictly planktonic feeders as reported by others (Cohen, 1954; Berg 1948-49) but rather, they are very much opportunistic feeders and generalists. Results concur with observations by Nikolsky (1961) of suspension of feeding prior to spawning in this species.

Parasites

A series of autopsies were made on least cisco from the 3 study populations in 1972.

Identifications were made by Mr. Gary Couture and verified by Dr. W. M. Samuel, Department of Zoology, University of Alberta.

Results of 23 autopsies are presented in Table 18. All 3 populations were parasitized to some degree, however the intensity appears to be greatest in the land-locked populations. Intensity of infection and salinity have been found to be inversely related in the brackish waters of the river Malyi Uzen, USSR (Dubinin, 1948).

The most obvious parasite observed during field dissections were the cestode pleuroceroid cysts on the stomach wall. The maximum intensity observed in the 2 parasite species involved during autopsy was 48, however on several occasions, infections in excess of 100 were observed on a single stomach. Such intense infections must result in some pathogenic effects.

The next most common parasites found were 3 and possible 4 species of Acanthocephala in the intestine. Two species could not be

TABLE 18: Parasite autopsy results.

Parasite	Location	N	Occurrence	Intensity
Trout Lake:				
Trematoda:				
a) *Discocotyle salmonis*	gill filaments	5	2	38,43
b) *Tetroacotyle intermedia* (metacercaria)	heart	5	5	53,35,7,4,3
Acanthocephala:				
a) *Metechinorhynchus salmonis*	intestine	5	4	7,4,6,6
b) *Neoechinorhynchus tumidus*	intestine	5	3	6,3,2
Lake 105:				
Cestoda:				
a) *Diphyllobothrium strictum*(L) (plerocercoid cysts)	stomach wall	8	8	5,16,41,7,27, 19,12,48
Acanthocephala:				
a) *Metechinorhynchus* sp.	intestine	8	2	7,4
b) *M. salmonis*	intestine	8	6	17,2,6,17, 1,12
Phillips Bay:				
Cestoda:				
a) *Protocephalus exigur* (plerocercoid)	intestine	7	2	5,34
b) *D. strictum* (L)	stomach and upper int.	7	2	3,4
Acanthocephala:				
a) *M. salmonis*	intestine	7	1	4
b) *Neoechinorhynchus* sp.	intestine	7	1	1
No parasites found:	-	3	-	-

identified from existing literature.

Ecto-parasitic copepoda (*Salimincola* sp.) which were commonly found on Arctic cisco (*C. autumnalis*) from the brackish water areas were never found on least cisco captured in the same areas.

Lawler (1970) lists the species of parasites recorded from *C. sardinella* in the USSR. The following species recorded during the present study represent additions to this list for the least cisco of North America;

Trematoda:	*Discocotyle salmonis*
Acanthocephala:	*Metechinorhynchus salmonis*
	Neoechinorhynchus tumidus

Taxonomic Data

As mentioned previously, the least cisco species complex has been studied primarily in terms of its taxonomic status. *Coregonus sardinella* was first described by Valenciennes in 1848 from specimens collected in the Irtysh and Kolyma rivers in the USSR. (McPhail and Lindsey, 1970). The first North American record of the least cisco was made by Bean in 1889 from the Kobuk River, Alaska. He named his specimen *C. pusillus* which is presently considered a synonym for *C. sardinella*.

Soviet ichthyologists are currently in disagreement concerning the taxonomic status of *C. albula* and *C. sardinella* (Behnke, 1972). In some situations, these 2 groups are more obviously differentiated morphologically than in others. They are largely allopatric in their distrib-

ution. However, sympatric, reproductively-isolated subpopulations are known to occur for each group. Some authors consider *C. sardinella* to be conspecific with *C. albula* whereas others recognize *C. sardinella* as a full species. Behnke (1972) indicated that evaluation of meristic data from sympatric pairs shows closer similarity to 1 group or the other but not both.

Concerning evaluation of taxonomic status of *C. sardinella* in North America, Behnke (1972) states:

> "*C. sardinella* has not been sufficiently studied in North America to adequately determine the full range of divergence but McPhail and Lindsey (1970) discussed 3 groups differing in gill-raker number, coloration and size: the typical coastal form, a non-migratory form of the upper Yukon basin and a dwarf form in Naknek Lake and Lake Illiamna of the Bristol Bay region of Alaska."

McPhail and Lindsey (1970) report the following range of variation for taxonomic characters for North American least cisco:

1) The migratory (anadromous) form reaches a length of approximately 360 mm, the dorsal surface is usually heavily spotted and first-arch gillraker counts range from 48-53 (mean near 50).
2) The non-migratory form seldom exceeds 220 mm, the dorsal surfaces are never spotted and gillrakers range from 41-47 (mean near 45).
3) The only known exceptions at the time of these authors' publication were dwarf forms from 2 lakes in the Bristol Bay region of Alaska. They report that lengths did not exceed 150 mm and that gillraker counts were high (49 to 53).

4) The overall range for North American populations examined prior to 1970 was: gillrakers (total counts first-arch 42-53, lateral line scales; 78-98, pyloric caeca; 74-111 and vertebra; 58-64.

In the present study, the range of variation among meristic counts often exceeds that in the published data. Table 19 shows that mean gillraker counts are relatively low for all populations and that the low range of counts is extended to 39. Lateral line scale and vertebral counts closely approach the ranges published by McPhail and Lindsey (1970). The lower range for pyloric caeca counts is extended considerably to a low of 51.

Mean, standard deviation and range statistics for the 4 meristic counts taken in 5 populations are present in Table 19. Differences which occurred were tested for statistical significance by oneway analysis of variance (ANOVA) using a program entiled "ANOVA 2" on the APL 360 computer, University of Alberta Computing Services. (Sokal and Rohlf, 1969). Prior to testing, data were tested for goodness of fit to normal distribution using the "Kolmogorov-Smirnov" test. (Sokal and Rohlf, 1969). All data were found to be normally distributed.

Of all populations tested, brackish water least cisco were found to differ most significantly from other populations in terms of 3 of the 4 characters tested (Table 20). Pyloric caeca and lateral line scale counts were significantly lower ($P<0.1$) in this population than in all other populations with which it was compared. Among freshwater normal populations, Trout Lake and Lake 105 differed the least

TABLE 19: Taxonomic data: meristic counts

	Gillrakers (Total)				Pyloric Caeca				Lateral Line Scales				Vertebrae			
Population	N	Mean	±SD	Range	N	Mean	±SD	Range	N	Mean	±SD	Range	N	Mean	±	Range
Trout Lake; "Normal"	18	43.55	2.0356	40-48	20	87.45	9.9920	76-106	34	84.94	3.2747	81-91	32	58.87	0.7399	58-61
Trout Lake; "Dwarf"	19	41.42	5.3684	39-46	20	80.30	10.7366	68-104	-	-	-	-	10	59.6	0.5164	59-60
Lake 105:	26	44.46	1.5806	41-47	19	83.68	10.1327	66-101	20	83.7	2.4516	81-89	-	-	-	-
Brackish Water Stations:	30	44.63	1.8659	41-48	22	68.23	9.3703	51-83	18	79.06	3.6051	74-85	-	-	-	-
Peter Lake; "Normal"	25	44.88	1.6663	42-48	25	85.92	9.9243	71-106	25	82.88	2.5053	78-89	25	60.64	1.3808	58-63

TABLE 20: Comparisons of meristic counts by one-way AVONA.
n.s.=$P>.05$, *=$P<.05$, **=$P<.01$, n.d.=no data.

	Trout L. "N"	Trout L. "D"	Lake 105	Brackish Waters	Peter L. "N"
Gillrakers (Total):					
Trout Lake "N"		*	n.s.	n.s.	*
Trout Lake "D"			**	**	**
Lake 105				n.s.	n.s.
Brackish Waters					n.s.
Peter Lake "N"					
Pyloric Caeca:					
Trout Lake "N"		*	n.s.	**	n.s.
Trout Lake "D"			n.s.	**	n.s.
Lake 105				**	n.s.
Brackish Waters					**
Peter Lake "N"					
Lateral Line Scales:					
Trout Lake "N"		n.d.	n.s.	**	**
Trout Lake "D"			n.d.	n.d.	n.d.
Lake 105				**	n.s.
Brackish Waters					**
Peter Lake "N"					
Vertebrae:					
Trout Lake "N"		*	n.d.	n.d.	**
Trout Lake "D"			n.d.	n.d.	*
Peter Lake "N"					

and Trout Lake and Peter Lake normals differed most frequently in meristic counts.

Trout Lake dwarf cisco were found to have significantly lower gillraker counts than Trout Lake normals ($P < .05$) and significantly lower counts than in all other populations with which it was compared ($P < .01$). This finding contrasts with reports of extremely high gillraker counts for Bristol Bay area dwarf fish, reported by McPhail and Lindsey (1970).

Vertebra counts are presently available from only 3 of the populations studied. The sample size for Trout Lake dwarf fish is small due to poor resolution in X-ray photographs. Peter Lake normals were found to have significantly more vertebrae ($P < 01$) than Trout Lake normals.

Dorsal spotting was not commonly observed on least cisco captured in brackish water or in most freshwater locations. Cohen (1954) reported that near Point Barrow, cisco captured in fresh water were never spotted on the dorsal surface. In contrast, normal, mature least cisco captured in Trout Lake during the present study exhibited prominent spotting on the dorsal surface of the head and around dorsal scale margins (Plate 18).

Coregonus sardinella survived the Wisconsin glaciation in a single refugium (Bering refuge) and dispersed eastward along the Beaufort Sea coast (McPhail and Lindsey, 1970). The observed differences in life history, growth patterns and meristic characters can be for the most part, attributed to the differential adaptation to environments encountered during this dispersal. However, the sympatric

Plate 18. Prominent dorsal spotting on mature "normal" least cisco from Trout Lake (bottom).
Middle: immature "normal".
Top: mature "dwarf" least cisco from Trout Lake.

occurrence in the same lakes of dwarf and normal growth types is not readily explained. The extent of divergence between these 2 groups could not be completely documented during the present study, however, future work to this end is planned, including examination of protein banding patterns in electrophoresis. It is possible that dwarfs and normals represent the result of dispersal into the lakes at 2 different times. Another possibility is that these 2 forms developed sympatrically. However, sympatric development of these pairs seems unlikely because of the observed overlap of niches, particularly in Trout Lake. The extent of hybridization between the 2 growth forms was not documented since hybrids could not be recognized, however, the persistence of sympatric dwarfs and normals suggests that introgression due to hybridization must be minimal.

The documentation of isolating mechanisms involved here is cause for future studies, however, present studies suggest that differing time of spawning and possibly spawning site selection may be involved.

SUMMARY

1) Least cisco were captured during the summer months of 1972 and 1973 from lakes and the coastal areas of the Yukon Territory North Slope, and Mackenzie River Delta areas. Most fish were caught in gill-nets and seines. A total of 1,544 cisco were sampled for information including: length, weight, sex, state of maturity and condition, gonad width and weight, stomach contents. Ages were determined from both otoliths and scales; however, otolith ages were assumed to be more reliable.

2) Life-history types examined included anadromous (migratory into coastal brackish waters), freshwater migratory, and non-migratory (freshwater lake-resident) types.

3) Among freshwater populations, 2 instances of sympatric normal and dwarf growth types are described (Trout Lake, Yukon Territory and Peter Lake, Northwest Territories).

4) Growth curves for normal freshwater-resident least cisco differ markedly from marine migratory forms in the greater longevity and a much shorter maximum length in the freshwater lake populations. Growth in length in all normal populations examined becomes asymptotic

at approximately age 10 years ($\pm$ 2 years). Growth in the first 10 years of life occurs most rapidly in brackish water - migratory least cisco.

5) Dwarf populations of cisco examined do not show significant growth in length after sexual maturity is reached. Dwarf fish were indistinguishable from young juvenile normals in external appearance, and could be recognized only by dissection to reveal advanced gonad development.

6) Young-of-the-year are hatched under the ice prior to spring breakup at a length of approximately 8-10 mm. Growth occurs rapidly during July and August and fry attain a length of approximately 45 mm before fall freeze-over.

7) Length-weight relationships typically showed a high degree of regression correlation ($r > .7000$) and little intra-population variation in slope or elevation when compared on the basis of sex and state of maturity. In interpopulation comparisons of regression lines by ANOVA, Lake 105 and Peter Lake normal cisco were found to differ most commonly from other populations in slope and elevation ($p > .05$).

8) Normal least cisco appear to begin maturing at age 5 or 6 in most populations but 100% maturity does not occur until age 7 or 8. Males did not significantly precede females in attaining maturity. In freshwater populations, a small percentage of mature individuals showed inability to spawn in successive years. This observation was

most common among females, and among the older individuals (age 12+ years).

Dwarf specimens mature at age 3 in both populations examined. Inability to spawn in successive years was commonly found among older (7+ years) Trout Lake dwarf fish.

9) Egg development proceeds at a relatively constant rate from spring (diameter approximately 0.5 mm) to late fall (diameter approximately 1.5 mm). In spite of their smaller body size, dwarf fish appear to develop slightly larger eggs, on the average, than normals by spawning time.

10) Among freshwater populations, spawning occurs somewhat earlier in Peter Lake than in the Yukon North Slope study area. In Peter Lake, ripe dwarf fish were captured in early September and ripe normals by mid-September. Both dwarf and normal fish in Trout Lake appear to spawn in early October, after freeze-over has occurred.

11) Fecundity-length and fecundity-weight relationships had typically low correlation coefficients; only the Peter Lake normal, Lake 105 and Trout Lake dwarf populations showed significant ($p<0.05$) regression coefficients. Analysis of covariance showed significant differences in slope and elevation of regression lines in all inter-population comparisons of fecundity-length relationships. No significant differences were found in comparisons of weight-fecundity relationships.

12) Brackish-water least cisco appear to disperse westward from the Mackenzie delta area along the North Slope in spring and summer and return to the delta by late August. This dispersing population along the North Slope coast is primarily made up of immature and mature non-spawning individuals.

13) Young-of-the-year least cisco from 2 North Slope lakes were observed to move into shallow water near shore (<1.5M in depth) during periods of minimal wind action. Fry appear to avoid areas of aquatic vegetation but showed no definite preference for a particular bottom type.

14) Least cisco in the study areas appear to be generalized and opportunistic feeders since a wide variety of food items commonly occurred in stomach analysis throughout the study periods. Bottom, pelagic and surface food items were found, including insect, crustacean, molluscan and fish material. Both dwarf and normal fish appear to terminate feeding during spawning but commence again shortly afterwards.

15) Freshwater populations of least cisco appear to be more heavily parasitized than the marine-migratory population examined. Cestode pleurocercoid cysts on the stomach wall were the most intense parasite infections observed.

16) Results of some of the meristic counts indicate close agreement with previously published ranges of variation, whereas others

considerably extend the range of counts for this species in North America. Brackish-water least cisco were found to differ most significantly from other populations in meristic counts. Trout Lake dwarf fish had significantly lower total gillraker counts than all other populations with which they were compared.

LITERATURE CITED

Alm, G. 1959. Connection between maturity, size and age in fishes. Fish. Bd. Sweden, Rept. Inst. Freshwater Res. Drottningholm, 40:5-145.

Alt, K. T. and D. R. Kogl. 1973. Notes on the Whitefish of the Colville River, Alaska. J. Fish. Res. Bd. of Can., 30(4):554-556.

Berg, L. S. 1948-49. Freshwater Fishes of the USSR and Adjacent Countries, (Translation) Zool. Inst. Akad. Nauk. 27,39,30.

Behnke, R. J. 1972. The systematics of salmonid fishes of recently glaciated lakes. J. Fish. Res. Bd. of Can., 29(6):639-671.

Burns, B. M. 1972. The climate of the Mackenzie Valley-Beaufort Sea. Vol. I. Climatelogical studies No. 24, Environment- Can. Atmospheric Environment. 227 p.

Cohen, D. M. 1954. Age and growth studies on two species of whitefish from Point Barrow, Alaska. Stanf. Ichthy. Bull. 4(3):168-188.

deBruyn, M. and P. J. McCart. 1973. Life history of grayling *(Thymallus arcticus)* in Beaufort Sea drainages in the Yukon Territory. Unpublished report to Northern Engineering Services Ltd., Calgary, Alberta. 33 p.

DeVries, A. L. 1971. Freezing resistance in fishes. IN W. S. Hoar and D. J. Randall (ed). Fish Physiology, Vol. VI. Academic Press. 559 p.

Dryden, R. L., B. A. Sutherland and J. N. Stein. 1973. An evaluation of the fish resources of the Mackenzie River Valley as related to Pipeline development. Vol. II Environ.-social committee Northern Pipelines, Task Force on Northern Oil Development. Rept. No. 73-2.

Dubinin, J. B. 1948. The influence of increased salinity of the Malgi Uzen on the parasite fauna of its fishes. Zool. Zh., XXVII,4.

Eschmeyer, P. H. and R. B. Bailey, 1955. The Pygmy Whitefish, *Coregonus coulteri*, in Lake Superior. Trans. Amer. Fish. Soc. 84:161-199.

Faber, D. J. 1968. A net for catching limnetic fry. Trans. Amer. Fish. Soc. 97(1):61-63.

Fenderson, O. C. 1964. Evidence of sub-populations of lake whitefish *(Coregonus clupeaformis)* involving a dwarfed form. Trans.

Amer. Fish. Soc. 93(1):77-94.

Hatfield, C. T., J. N. Stein, M. R. Falk and C. S. Jessop. 1972. Fish Resources of the Mackenzie River Valley. Interim Report 1, Vols. I and II. Environment Can. Fisheries Service. 247 p.

Hubbs, C. L. and K. F. Lagler. 1958. Fishes of the Great Lakes region. Bull. Cranbrook Res. Inst. Sci. 26(revised): 213 p.

Hughes, O. L. 1972. Surficial geology of Northern Yukon Territory and northwest district of Mackenzie, N.W.T. Geol. Surv.Can. Pap.:69-36.

Kennedy, W. A. 1943. The whitefish, *Coregonus clupeaformis* (Mitchill) of Lake Opeongo, Algonquin Park, Ontario. Publ. Ontario Fish Res. Lab. No. 62, pp 23-66.

_______________ 1954. Growth, maturity and mortality in the relatively unexploited lake trout, *Cristivomer namaycush*, of Great Slave Lake. J. Fish. Res. Bd. Can. 11:827-853.

Kogl, D. R. 1972. Monitoring and evaluation of Arctic waters with emphasis on the North Slope drainages: Colville River study. Job 6-111-A, Project F-9-3, Alaska Dept. of Fish and Game, Div. of Sport Fish.

Lagler, K. F. 1952. <u>Freshwater Fishery Biology</u>. W. C. Brown, Co., Dubuque, Iowa. 421 p.

Lawler, G. H. 1970. Parasites of Coregonid fishes, <u>IN</u> C. C. Lindsey and C. S. Woods (ed), <u>Biology of Coregonid Fishes</u>, Univ. of Manitoba Press, Wpg:279-309.

Lindsey, C. C. 1961. Sympatric occurrence of two species of humpback whitefish in Squanga Lake, Yukon Territory. J. Fish. Res. Bd. Can., 20(3):739-767.

Lindsey, C. C. 1962. Distinctions between the broad whitefish *Coregonus nasus* and other North American whitefishes. J. Fish. Res. Bd. Can., 19(4):687-714.

Lindström, T. and N. A. Nilsson. 1962. On the competition between whitefish species. <u>IN</u> E. C. LeCren and M. W. Holdgate (ed), <u>The exploitation of natural animal populations</u>, British Eco. l Soc. Symp. No. 2, Blackwell, Oxford. pp 326-340.

Lux, F. E. 1971. Age determination of fishes (revised). US Natnl. Marine Fish. Ser., Fishery Leaflet 637, 7 p.

Miller, R. B. and W. A. Kennedy, 1948. Observations on the lake trout of Great Bear Lake. J. Fish. Res. Bd. Canada 7:176-189.

McCart, P. J. 1970. Evidence for the existence of sibling species of pygmy whitefish *(Prosopium coulteri)* in three Alaskan lakes. IN C. C. Lindsey and C. S. Woods (ed) Biology of Coregonid Fishes. Univ. of Man. Press, Wpg.:81-98.

McCart, P. J., P. Craig, H. Bain, 1972. Report on Fisheries investigations in the Sagavanirktok River and neighboring drainages. Rept. to Alyeska Pipeline Service Company. 83 p.

McPhail, J. D. and C. C. Lindsey, 1970. The Freshwater Fishes of Northwestern Canada and Alaska, Bull. Fish. Res. Bd. Can., 173: 381 p.

Nikolsky, G. V. 1961. (Special Ichthyology) 2nd. Ed. (In Russian; English translation by Israel Program for Sci. Transl. Jerusalem, 1961) 538 p.

______________ and Yu. S. Reshetnikov, 1970. Systematics of Coregonid Fishes in the USSR: Intraspecies variability and difficulties in taxonomy, IN C. C. Lindsey and C. S. Woods (ed) Biology of Coregonid Fishes. Univ. of Man. Press, Wpg: 81-98.

Nordeng, H. 1961. On the biology of char *(Salvelinus alpinus L.)* in Salangen, North Norway. Zoologi 10:67-121.

Rawson, D. S. 1961. The lake trout of Lac la Ronge, Sask. J. Fish. Res. Bd. Can.,18(3):423-462.

Ricker, W. E. 1968. Methods for assessment of Fish production in fresh waters. IBP Handbook No. 3, Blackwell Scientific Publications, Oxford and Edinburgh, 313 p.

Sokal and Rohlf, 1969. Biometry: The principles and practice of statistics in biological research. W. H. Freeman and Compan, San Francisco. 776 p.

Stein, J. N., C. S. Jessop, T. R. Porter and K. T. J. Chang-Kue, 1973. An evaluation of the fish resources of the Mackenzie River Valley as related to pipeline development. Vol. I, Environmental-Social Committee Northern Pipelines, Task Force on Northern Oil Development, Rept. No. 73-1:121 p.

Svärdson, G. 1957. The Coregonid problem. VI The palearctic species and their intergrades. Fish. Bd. Sweden. Rept. Inst. Freshwater Res. Drottningholm, 38:267-356.

Venglinskii, D. L. 1967. Biological characteristics of certain commercial fish of the OB north. (NRC Translation series) Problems of the North, 11:235-256.

Walters, V. 1955. Fishes of western Arctic America and eastern Arctic

Siberia. Bull. Am. Museum Nat. Hist. 196-255-368.

Wohlschlag, D. E. 1953. Some characteristics of the fish populations in an Arctic Alaskan Lake. Stanf. Univ. Publ., Univ. Ser. Biol. Sci. 11:19-29.

Wohlschlag, D. E. 1954. Growth peculiarities of the cisco, *Coregonus sardinella* (Val.) in the vicinity of Point Barrow, Alaska. Stanf. Ichthyol. Bull.4:189-209.

Wohlschlag, D. E. 1956. Information from studies of marked fishes in the Alaskan Arctic. Copeia 4:237-442.

Wynne-Edwards, V. C. 1952. Freshwater vertebrates of the Arctic and sub-Arctic. Bull. Fish. Res. Bd. Can.,94, 28 p.

APPENDICES

Appendix 1:

NORTH SLOPE AND N.W.T. SAMPLING SITES

1. Species Lists	Abundance[1] 1972	1973
Clarence Lagoon:		
Coregonus autumnalis (Pallas): Arctic Cisco	++	xx
Myoxocephalus quadricornis quadricornis (Linnaeus): Fourhorn Sculpin	++	xx
Liopsetta glacialis (Pallas): Arctic Flounder	+	xx
Firth River Delta, Nunaluk Spit, Herschel Island:		
C. autumnalis: Arctic Cisco	++	xx
C. sardinella (Vallenciennes): Least Cisco	+	xx
M. q. quadricornis: Fourhorn Sculpin	+	xx
L. glacialis: Arctic Flounder	+	xx
Salvelinus alpinus (Linnaeus):Arctic Char	--	xx
Phillips Bay, Lake 106:		
C. autumnalis: Arctic Cisco	+	+
C. sardinella: Least Cisco	++	+
C. nelsoni (Bean): Humpback Whitefish	--	0
C. nasus (Pallas): Broad Whitefish	--	0
Stenodus leucichthys nelma (Pallas)Inconnu	--	0
Thymallus arcticus (Pallas): Arctic Grayling	--	0
Salvelinus alpinus: Arctic Char	0	+
Osmerus eperlanus (Linnaeus): Boreal Smelt	--	0
Clupea harengus pallasi (Vall.): Herring	--	0
M. q. quadricornis: Fourhorn Sculpin	++	++
L. glacialis: Arctic Flounder	++	0
Boreogadus saida (Lepechin): Arctic Cod	0	--
Stokes Point Lagoon:		
Coregonus autumnalis: Arctic Cisco	xx	++
C. sardinella: Least Cisco	xx	+
C. nelsoni: Humpback Whitefish	xx	--
Stenodus l nelma: Inconnu	xx	+
Salvelinus alpinus: Arctic Char	xx	--
M. q. quadricornis: Fourhorn Sculpin	xx	++

Appendix 1:(continued)

	Abundance [1] 1972	1973
Trout Lake:		
C. sardinella: Least Cisco	++	++
C. nasus: Broad Whitefish	--	--
Prosopium cylindraceum (Pallas):Round Whitefish	--	--
T. arcticus: Arctic grayling	+	+
Pungitius pungitius (Linnaeus):Nine-spine Stickleback	++	++
Lake 105:		
C. sardinella: Least Cisco	++	++
T. arcticus: Arctic Grayling	+	+
Salvelinus namaycush (Walbaum): Lake Trout	+	+
P. pungitius: Nine-spine Stickleback	++	++
Peter Lake, N.W.T.		
C. nelsoni: Humpback Whitefish	xx	+
C. nasus: Broad Whitefish	xx	+
C. sardinella: Least Cisco (in Sept. only)....	xx	++
P. cylindraceum: Round Whitefish	xx	+
T. arcticus: Arctic Grayling	xx	--
S. namaycush: Lake Trout	xx	+
Cottus cognatus (Richardson): Slimy Sculpin	xx	--

1 Abundance Code:
- xx: samples not taken
- 0: absent from samples
- --: rarely taken in samples
- +: commonly taken in samples
- ++: commonly taken and very abundant in samples

Appendix 2:

CATCH SUMMARY: 1972 - 1973

Collection Number	Date		Number of Least Cisco	Length Range (mm)
Trout Lake, 1972:				
N72 42	Jun.	29	28	117 to 318
N72 53	Jul.	9	4	125 to 301
N72 54	Jul.	11	56	82 to 318
N72 71	Jul.	26	44	89 to 300
N72 104	Aug.	6	6	33 to 131
N72 111	Aug.	9	18	138 to 322
N72 119	Aug.	11	5	272 to 305
N72 135	Aug.	19	7	39 to 307
N72 141	Aug.	22	52	42 to 142
N72 144	Aug.	23	200	35 to 304
N72 171	Aug.	31	2	284 to 299
N72 206	Sept.	12	3	194 to 339
Lake 105, 1972:				
N72 55	Jul.	11	24	92 to 257
N72 67	Jul.	25	14	195 to 290
N72 68	Jul.	25	5	157 to 271
N72 120	Aug.	11	81	125 to 311
N72 137	Aug.	20	111	160 to 245
N72 192	Sept.	9	20	150 to 256
Firth Delta, Nunaluk Spit, Herschel Island: 1972:				
N72 36	Jun.	23	1	337
N72 105	Aug.	8	31	111 to 319
Phillips Bay, Lake 106, Spring River, 1972:				
N72 62	Jul.	18	49	183 to 312
N72 63	Jul.	21	49	88 to 334
N72 86	Aug.	1	3	314 to 328
N72 194	Sept.	16	7	150 to 273
Total LSCS Catch, 1972:			789	

Appendix 2: (continued)

Collection Number	Date	Number of Least Cisco	Length Range (mm)
Trout Lake, 1973:			
N73 44	Jul. 3	41	131 to 313
N73 62	Jul. 19	12	97 to 298
N73 65	Jul. 22	16	89 to 106
N73 119	Jul. 30	50	17 to 25
N73 120	Jul. 30	21	87 to 117
N73 122	Jul. 31	47	86 to 154
N73 130	Aug. 19	13	27 to 38
N73 146	Aug. 29	7	93 to 307
N73 164	Sept. 12	6	96 to 310
N73 179	Sept. 13	131	87 to 243
N73 182	Sept. 25	33	91 to 309
Lake 105, 1973:			
N73 63	Jul. 21	4	91 to 96
N73 66	Jul. 22	38	87 to 105
N73 81	Aug. 8	38	21 to 72
N73 145	Aug. 29	1	38
N73 175	Sept. 16	20	36 to 48
Sabine Lake, 1973:			
N73 80	Aug. 7	29	119 to 295
N73 148	Aug. 29	11	182 to 282
Phillips Bay, 1973:			
N73 33	Jun. 21	2	180 to 209
N73 35	Jun. 22	8	255 to 317
Stokes Point Lagoon, 1973:			
N73 79	Aug. 6	12	250 to 313
N73 100	Jul. 23	7	176 to 312
N73 143	Aug. 27	1	313
Peter Lake (N.W.T.), 1973:			
N73 153	Sept. 4	96	113 to 267
N73 158	Sept. 10	38	113 to 154
N73 180	Sept. 20	34	151 to 263
Yeltea Lake, (N.W.T.), 1973:			
N73 23	Jun. 17	2	135 to 140

Appendix 2:(continued)

Collection Number	Date	Number of Least Cisco	Length Range (mm)
Lake 73: 1:2, (N.W.T.), 1973:			
N73 110	Jul. 27	3	246 to 318
N73 160	Sept. 9	2	201 to 316
Holmes Creek, (N.W.T.), 1973:			
N73 135	Aug. 20	32	38 to 62
Total LSCS Catch, 1973:		755	
Grand Total, 1973,1973:		1,544 Least Cisco sampled from Study Area.	

Appendix 3:

SAMPLING GEAR SELECTIVITY

Trout Lake (1972 Data)

Gill Nets:

Age:	0	1	2	3	4	5	6	7	8	9	10	11	12	13+
Mesh Size														
1.3cm(3/4")	0	4	11	50	18	1	0	0	0	0	1	1	0	5
2.5cm(1")	0	0	0	4	9	0	2	1	0	0	2	0	1	1
3.8cm(1-1/2")	0	0	0	0	0	0	0	0	1	1	0	0	1	2
5.1cm(2")	0	0	0	0	0	1	6	2	0	0	3	0	2	17
6.3cm(2-1/2")	0	0	0	0	0	1	0	0	0	1	0	0	0	2
7.3cm(3")	0	0	0	0	0	0	0	0	0	0	0	0	0	5
8.9cm(3-1/2")	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Seine Nets:	65	10	32	0	8	3	2	1	0	0	0	1	0	1
Hoop Net:	0	0	0	0	0	0	0	0	0	0	0	0	0	8

Lake 105 (1972 Data)

Mesh Size														
1.3cm(3/4")	0	3	0	0	0	0	0	0	0	0	0	0	0	0
2.5cm(1")	0	0	1	41	3	0	0	0	1	0	0	0	0	3
3.8cm(1-1/2")	0	0	1	7	12	13	9	3	7	0	7	6	5	21
5.1cm(2")	0	0	0	0	0	0	0	0	0	2	1	2	5	31

Brackish Water Stations (1972 Data)

Mesh Size														
1.3cm(3/4")	0	4	3	1	1	0	0	0	0	0	0	0	0	0
2.5cm(1")	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.8cm(1-1/2")	0	0	2	13	27	22	18	2	1	1	3	0	0	3
5.1cm(2")	0	0	0	2	3	4	3	2	5	3	2	0	0	1
6.3cm(2-1/2")	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.3cm(3")	0	0	0	0	0	1	1	0	0	1	0	1	0	0
8.9cm(3-1/2")	0	0	0	0	0	0	0	0	0	0	0	1	0	1
10.2cm(4")	0	0	0	0	0	0	0	1	0	0	0	0	0	0

Appendix 4:

Northern Engineering Services Limited

FISH COLLECTION DATA SHEET

COLLECTION NO. N72-999

LOCATION Trout Lake

DATE July 1, 1972

SAMPLED BY G.Mann,H.Bain

SAMP NO	SPECIES	LENGTH (mm)	WEIGHT (gm)	SEX	MAT	COND	EGGS		GONAD		AGE		TAG NO	CAPT	STOMACH CONTENTS	OTHER INFORMATION	
							SIZE (mm)	NO	WEIGHT (gm)	WIDTH (mm)	SC	OTO					
1	LSCS	200	200.1	F	I	-	<.1	-	1.1	5.1	6 ✓	7 ✓	-	GN	50% Full Gastropoda	Lateral Line	Scales:86
2	LSCS	314	285.6	F	M	G	1.3	14281	15.6	12.0	20 ✓	23 ✓	-	HP	Empty	LLS=91	

SAMPLE DATA SHEET: DATA FICTITIOUS

Appendix 5:

SALINITY - TEMPERATURE PROFILES TAKEN IN BRACKISH WATER AREAS

1972 - 1973

Location	Date	Depth	Temp. (^{o}C)	Salinity (ppt) (Corrected for temperature)
Clarence Lagoon area (Seaward side of Barrier Beach)	Jul. 3/72	Surface	9.5	<1.0
		Bottom (2m)	5.0	27.0
Nunaluk Spit	Jul.13/72	Surface	12.0	<1.0
		2.5 m	3.0	29.0
		Bottom (4m)	3.5	29.0
Phillips Bay	Jul.18/72	Surface	16.0	<1.0
		0.75 m	16.0	<1.0
		Bottom (1.5m)	15.0	2.5
Nunaluk Spit	Aug. 6/72	Surface	12.0	<1.0
		1.0 m	4.0	29.0
		Bottom (1.5m)	3.8	30.0
Beaufort Sea (1 mi north of Nunaluk Spit)	Aug. 6/72	Surface	5.0	30.0
		Bottom (8m)	3.5	32.0
Phillips Bay	Jun.21/73	Surface	6.5	<1.0
		1.0 m	6.2	<1.0
		Bottom (2.0m)	6.0	<1.0
Phillips Bay	Jul.20/73	Surface	7.0	<1.0
		Bottom (2.0m)	7.0	1.0
Stokes Point Lagoon	Jul.23/73	Surface	6.5	2.0
		2 m	5.9	2.0
		Bottom (2.5m)	4.5	33.0
Beaufort Sea (1/4mi north of Stokes Pt.Lag.)	Jul.23/73	Surface	5.0	2.0
		3 m	4.0	13.0
		Bottom (6m)	3.5	17.0
Stokes Point Lagoon	Aug. 6/73	Surface	13.5	9.0
		2.0 m	11.8	12.0
		Bottom (3.5m)	10.2	15.0
Stokes Point Lagoon	Aug.27/73	Surface	6.9	20.5*
		Bottom (3.5m)	5.8	24.0*

Appendix 5: (continued)

Location	Date	Depth	Temp. (^{o}C)	Salinity (ppt) (Corrected for temperature)
Stokes Point Lagoon	Sept.12/73	Surface	6.5	9.0*
		2.0 m	6.0	18.0*
		Bottom (3.5m)	5.5	24.0*

*Approximated since densities fell within range of broken hydrometer.

Appendix 6: Fecundity data for least cisco from various localities. DC indicates fecundity determined by direct count and SS indicates fecundity determined by subsample techniques.

	Normal Population		
	Fork Length	Weight: gm	Fecundity
Trout Lake:	262	192.9	7,886 (DC)
	271	216.2	10,353 (DC)
	322	315.7	9,462 (SS)
	294	285.3	16,400 (SS)
	314	335.7	11,402 (SS)
	288	258.7	15,254 (SS)
	300	265	12,827 (SS)
	300	270.1	9,886 (SS)
	313	291.6	19,261 (SS)
	304	326.5	9,026 (SS)
	310	309.5	9,282 (SS)
	305	302.6	12,115 (SS)
	308	312.1	13,618 (SS)

	Dwarf Population		
	Fork Length	Weight: gm	Fecundity
Trout Lake:	111	9.9	545 (DC)
	95	7.4	574 (DC)
	106	9.8	672 (DC)
	96	6.8	336 (DC)
	95	7.6	410 (DC)
	109	11.0	404 (DC)
	100	9.5	477 (DC)
	92	7.0	362 (DC)
	110	10.1	377 (DC)
	90	6.7	340 (DC)
	110	12.1	631 (DC)
	87	6.6	473 (DC)
	90	6.7	410 (DC)
	101	8.8	382 (DC)

Appendix 6: Continued

	Dwarf Population (Cont'd.)		
	Fork Length	Weight: gm	Fecundity
Trout Lake:	91	6.6	328 (DC)
	93	7.5	308 (DC)
	90	6.8	435 (DC)
	97	7.8	365 (DC)
	103	18.5	570 (DC)
	88	7.1	349 (DC)
	95	7.2	323 (DC)
	103	8.8	351 (DC)
	103	10.3	465 (DC)
	100	9.7	455 (DC)
	90	7.8	295 (DC)
	95	8.4	393 (DC)
	96	8.8	373 (DC)
	88	7.6	553 (DC)
	89	7.3	253 (DC)
	92	8.2	444 (DC)
	91	7.6	372 (DC)
	96	8.1	223 (DC)
	92	7.8	339 (DC)

	Normal Population		
	Fork Length	Weight: gm	Fecundity
Peter Lake:	240	146.1	4,800 (SS)
	242	165.2	9,505 (SS)
	247	166.0	5,613 (SS)
	247	148.4	6,129 (SS)
	258	165.4	6,163 (SS)
	246	156.9	5,368 (SS)
	237	141.0	5,113 (SS)
	226	123.1	3,787 (SS)
	241	156	4,526 (SS)
	255	182.6	6,213 (SS)

Appendix 6: Continued

Normal Population (Cont'd.)

	Fork Length	Weight: gm	Fecundity
Peter Lake:	232	132.5	3,879 (SS)
	248	154.1	5,680 (SS)
	226	123.7	3,550 (SS)
	241	137.7	4,928 (SS)
	252	157.7	4,806 (SS)
	240	158.6	6,972 (SS)
	253	178.3	5,710 (SS)
	251	153.9	6,936 (SS)
	232	133.1	5,576 (SS)
	231	136.3	4,224 (SS)
	244	147.5	6,228 (SS)
	253	150.5	4,931 (SS)
	239	142.4	5,214 (SS)
	231	124.7	3,313 (SS)
	255	158.4	3,283 (SS)
	221	121.1	3,594 (SS)
	249	146.0	5,233 (SS)
	233	109.5	5,722 (SS)

Dwarf Population

	Fork Length	Weight: gm	Fecundity
Peter Lake:	130	20.0	1,080 (DC)
	120	16.6	868 (DC)

	Fork Length	Weight: gm	Fecundity
Lake 105:	242	165.4	6,623 (DC)
	221	118.0	4,260 (DC)
	230	130.3	4,403 (DC)
	250	166.2	4,073 (SS)
	244	163.6	5,765 (SS)
	263	211.7	5,761 (SS)
	209	133.1	4,295 (SS)

Appendix 6: Continued

	Fork Length	Weight: gm	Fecundity
Lake 105: continued	222	125.3	4,428 (SS)
	241	136.9	4,549 (SS)
	256	177.3	5,271 (SS)
	225	110.5	3,918 (SS)
	237	148.9	4,677 (SS)
	229	129.9	5,602 (SS)
	230	132.9	5,538 (SS)
	236	150.5	5,073 (SS)
	266	239.8	8,694 (SS)
	259	189.5	3,701 (SS)
	311	345.3	13,821 (SS)
	237	158.8	3,422 (SS)
	227	140.4	2,463 (SS)
	218	114.3	2,174 (SS)
	262	215.4	7,789 (SS)
Brackish Waters:	314	313.9	17,412 (SS)